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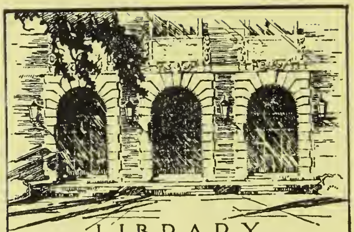

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Bulletin 252 December, 1919

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

HONEY AS A CARRIER OF INTESTINAL DISEASES

By
WALTER G. SACKETT

JUN 29 1945

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1919

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HONEY AS A CARRIER OF INTESTINAL DISEASES

By

WALTER G. SACKETT

APR 16 '47 PAYNE

Among the different articles of food which we have come to regard as possible carriers of the germs of the typhoid-colon group, no one appears to have suggested honey. This is rather surprising, considering the fact that it is consumed in a raw state, and that its occurence and use are quite general. The failure to include honey in the list is probably because the majority of investigators who are devoting their time to studies of this kind are not familiar either with the conditions under which honey is procured or with the habits of honey bees.

While pursuing another investigation in Tennessee during July, 1918, the writer frequently observed bees crawling over the human excrement of the family privy. This structure was quite typical of the farm privies of that section; no excavation had been made to receive the fecal matter, and to facilitate the removal of the latter, the lower part of the back side was not boarded up. Chickens, snakes, flies, and bees, all had free access thereto, and among them but little material was allowed to accumulate. Subsequent inquiry concerning this peculiar habit of honey bees has confirmed the writer's observations.

It is difficult to conceive of conditions better suited to the dissemination of intestinal bacteria than those afforded by the case just cited, and if an ideal opportunity was ever offered for the contamination of a food stuff, it should have been realized in the wax and honey produced by such bees. The possible relation of this subject to food poisoning seemed of sufficient importance to justify an inquiry into the behavior of intestinal bacteria in honey, and accordingly we have undertaken a study of the longevity of ten micro-organisms of this group in extracted honey.

MICRO-ORGANISMS OF THE APIARY

Before considering the experimental work with which this paper deals, a brief reference to the micro-organisms which have been found associated with bees and their products will be of interest.

From Combs

White[1] has isolated *Bacillus A* (*Bacillus mesentericus?*), *Bact. acidiformans*, and *Saccharomyces roseus* from combs.

From Pollen and Intestine of Healthy Honey Bees

From the pollen and intestine of the bee, White[1] has separated a motile rod, designated *Bacillus B* described briefly as follows:

Motile, Gram negative rod which liquefies gelatin slowly; egg yellow pigment; alkaline reaction in litmus milk; acid but no gas from dextrose; slight acid production from maltose and mannite; alkaline reaction with lactose, saccharose and levulose.

From Comb Honey and Healthy Larvae

The same author states that he has examined comb honey from a large number of sources and has found it to be quite uniformly sterile. Healthy larvae are likewise sterile. The writer has made similar examinations of comb honey from the local market and his findings confirm those of White.

Upon Adult Bees

White has noted *Bacillus A* (*B. mesentericus?*), *Bact. cyaneus* (*Micrococcus cyaneus*) and *Micrococcus C* as occurring upon adult bees.

Micrococcus C.—Non motile, Gram positive coccus; liquefies gelatin; produces acid from dextrose, lactose, saccharose, levulose, maltose, and mannite, but no gas; milk is coagulated and the casein is liquefied.

In Intestine of Healthy Honey Bee

According to White, the temperature of the healthy honey bee approximates that of warm blooded animals, and many of the same bacteria that occur in the bee's intestine are also found in the intestine of man and other animals. The number of species in any individual is comparatively small, altho the number of organisms may be large.

The list includes:

Bacillus cloacae
Bacillus coli communis
Bact. mycoides
Bacterium D.
Saccharomyces F.
Saccharomyces roseus

Bacillus cholerae suis
Bacillus sugastricus
Ps. fluorescens liquefaciens
Bacillus E.
Saccharomyces G.

Bacterium D.—Non-motile rod, non-spore-forming anaerobe; does not liquefy galatin; produces neither acid nor gas from dextrose.

Bacillus E.—Motile rod; does not produce spores, Gram positive; liquefies gelatin slowly; lemon yellow in color; produces acid from dextrose, saccharose, mannite; reaction alkaline with lactose, levulose, and maltose. Milk coagulated and casein slightly digested.

Bacillus alvei, believed for a long time to be the cause of European foul brood, is frequently found in dead larvae. Pollen stored in foul brood combs and likewise honey in brood combs infected with the disease contain relatively few germs. The surface of the combs, frames, and hives may be contaminated with it as well as the wings, head, legs, thorax, abdomen, and intestinal contents of adult bees.

Bacillus pluton, the true cause of European foul brood, according to White[2], and *Bacillus larvae,* the organism responsible for American foul brood, appear to be present in the honey of infected hives. In evidence of this, we find such statements as the following:—

"The honey from a diseased colony should be diluted to prevent burning and then thoroly sterilized by hard boiling for at least one-half hour, if it is to be fed back to the bees".[1]

"In order to kill the bacteria of either of the brood diseases, it is desirable to dilute the honey by adding an equal amount of water and then raising the temperature to the boiling point and keep it there, allowing the mixture to boil vigorously for at least 30 minutes; in order that no risk may be run, it is better to make this one hour".[3]

"The common means of carrying the virus is in honey which has become contaminated".[4]

Fermented and sour honey furnish additional evidence that micro-organisms are capable of living and developing in this medium. The exact nature of the fermentation appears to be somewhat uncertain, but it is probably both alcoholic and acid (acetic). These changes are observed most frequently in unripe honey, that in which the moisture content is more than 25 per cent. Such honey usually contains more succrose than the finished product and during the ripening process this is converted into invert sugar.

Shutt[5] states that honey from uncapped or only partially capped combs is usually immature, containing a higher percentage of moisture and having decidedly *poorer keeping qualities* than honey from fully capped combs.

Root[6], in commenting on *fermented* honey, says that "Probably not one beekeeper in a hundred can tell by the taste or appearance whether extracted honey when put up in cans and kept in a dry place is proof against *fermentation.** Part of a lot of honey, (granulated hard when first bought) tho kept in a warm, dry room, *fermented* and *expanded* the cans until they burst. This honey was not extremely sour to the taste, and yet there was a very perceptible flavor of *fermentation*, practically ruining the whole lot".

Again we read[7]:

"Can you give me a remedy for honey *souring* in the hive? . . . . It begins with a few small air bubbles in the cells, which increase in size and number until the cells are full, and a perceptible movement is obvious. This honey is very thin and sour".

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*Italics by the writer.

Cook[7], in commenting on this phenomenon, attributes the trouble to bacteria, adding that,

> "In the action of these germs, not only is acetic acid produced, but, as surely, carbon dioxide gas. Barrels of unripe honey are apt to burst from this cause".

Nussbaumer[8] has found several species of *zygosaccharomycetes* in honey, capable of inducing fermentation.

Farnsteiner[9] has studied the changes produced in sour honey by pasteurization.

Browne[10], who has made a very thoro study of the chemical composition of American honeys, explains the keeping quality of ripe honey, in a measure at least, thus:

> "Another modification produced in the nectar by the bees is the introduction of a minute quantity of formic acid. This acid is wanting in the pollen and nectar of flowers and is supposed to be introduced into the honey by the bee just previous to capping the cell. The formic acid thus introduced by the bee is supposed to act as a *preservative and prevent the honey from fermenting*".

These citations to the fermentation of honey have been introduced here as prima facie evidence in support of the contention that certain micro-organisms, at least, are able *to live in honey* and when once established *can bring about well recognized chemical changes.*

Browne gives the following composition of American honey:

Invert sugar	74.44 per cent.
Succrose	1.90 per cent.
Moisture	17.59 per cent.

Acidity (expressed as formic acid) varies from .04 to .25 per cent. with an average of .09 per cent.

To find bacteria thriving in as concentrated a solution as is represented by this analysis is rather unexpected, yet the facts in the case seem to bear this out with respect to the organisms mentioned above.

The fate of the members of the typhoid-colon group in this medium will be considered in the pages which follow.

PRESENT WORK

HONEY.—Extra fine, extracted, alfalfa honey, obtained directly from the producer in stock, five-pound tin pails, was used in the study. It was very light in color and had been heated but slightly to facilitate the extraction. It crystallized readily at 20° C. and was weighed in this form for the different dilutions employed.

The acidity, expressed as formic acid, was .11 per cent. for Lot No. 1 and .09 per cent. for Lot No. 2.

METHODS

DILUTIONS OF HONEY.—In order to determine the effect of the concentration of the honey upon the bacteria studied, the proper weights of crystallized honey were added to physiological salt solution (.85 per cent. NaCl in distilled water) to give the following percentage dilutions: 0.0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100.

25 c.c. portions of each dilution were measured into 100 c.c. Erlenmeyer flasks and sterilized for 30 minutes in flowing steam on three consecutive days.

CULTURES.—The following organisms were used in the experiment:

- *B. typhosus*
- *B. fecalis alkaligenes*
- *B. proteus vulgaris*
- *B. suipestifer*
- *B. lactis aerogenes*
- *B. paratyphosus "B"*
- *B. paratyphosus "A"*
- *B. coli communis*
- *B. dysenteriae*
- *B. enteritidis*

Suspensions of these were made in physiological salt solution from 48-hour agar strokes, and 1 c.c. of each was added to each flask of honey as an inoculum. The flasks were kept at room temperature.

To ascertain the approximate length of time that the cultures were able to survive in the honey, agar plates were made from the flask cultures, using one loop for the transfer, when the honey was first inoculated, after 5 and 10 hours, and daily thereafter for 12 days. In some cases the plating was continued for a longer period.

SERIES I.—NEW FALL HONEY

TABLE 1.—BACILLUS TYPHOSUS

Per cent. Honey	Longevity of Culture													
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	±*	—						
20.0	+	+	+	+	+	+	—							
30.0	+	+	+	+	+	+	—							
40.0	+	+	+	+	+	+	—							
50.0	+	+	+	+	+	—								
60.0	+	+	+	+	—									
70.0	+	+	+	+	—									
80.0	+	+	+	+	—									
90.0	+	+	+	+	—									
100.0	+	+	+	+	+	—								

*NOTE.—The character ±, wherever it occurs in the above and following tables, denotes a very marked reduction in the number of bacteria.

In the pure honey, *B. typhosus* remained alive for 48 hours. After 24 hours it was dead in dilutions above 50 per cent.; after 48 hours it had disappeared from the 50 per cent.; after 3 days it was alive only in the 10 per cent., and in the salt solution control, and after 4 days it was present only in the control, where it was still alive after 40 days.

TABLE 2.—BACILLUS FECALIS ALKALIGENES

Per cent. Honey	Longevity of Culture					
	0	5 hrs.	10 hrs.	1d.	2d.	40d.
0.0	+	+	+	+	+	+
10.0	+	+	+	—		
20.0	+	+	—			
30.0	+	+	—			
40.0	+	+	—			
50.0	+	—				
60.0	+	—				
70.0	+	—				
80.0	+	—				
90.0	+	—				
100.0	+	—				

B. fecalis alkaligenes appears to be the most sensitive of all the organisms studied. It was killed by all concentrations above 50 per cent., including pure honey, inside of 5 hours and after 10 hours remained alive only in the 10 per cent. and control; at the end of 24 hours it was present only in the control, where it was still alive after 40 days.

TABLE 3.—BACILLUS PROTEUS VULGARIS

Per cent. Honey	Longevity of Culture																
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	15d.	20d.	25d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	*
20.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	*
30.0	+	+	+	+	+	+	+	±	—								
40.0	+	+	+	+	+	—											
50.0	+	+	+	+	—												
60.0	+	+	+	+	—												
70.0	+	+	+	+	—												
80.0	+	+	+	+	—												
90.0	+	+	+	+	—												
100.0	+	+	+	+	+	+	±	—									

Bacillus proteus vulgaris was present in all concentrations during the first 24 hours; it died out in the pure honey after the fourth day. On the second day it had disappeared from all dilutions above 40 per cent., and on the third day it was absent from the 40 per cent. There was a very marked reduction in the number of bacteria in the 30 per cent. on the fifth day and all were dead on the sixth. The culture remained alive in the 10 per cent. and 20 per cent. for 25 days, at which time the platings were discontinued. The control culture in salt solution was still alive after 40 days.

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* Discontinued.

TABLE 4.—BACILLUS SUIPESTIFER

Per cent. Honey	Longevity of Culture														
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	11d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	±	—	
20.0	+	+	+	+	+	+	+	+	+	—					
30.0	+	+	+	+	+	+	+	+	—						
40.0	+	+	+	+	+	+	—								
50.0	+	+	+	+	+	—									
60.0	+	+	+	+	±	—									
70.0	+	+	+	+	±	—									
80.0	+	+	+	+	±	—									
90.0	+	+	+	+	±	—									
100.0	+	+	+	+	±	±	—								

Bacillus suipestifer survived all concentrations for 24 hours, but the number of bacteria was greatly reduced in the 60, 70, 80, and 90 per cent. in 48 hours; the culture was dead in the pure honey on the fourth day. On the third day all dilutions were dead above 40 per cent.; by the eighth day, the 10 per cent. and the control alone gave growth, the former showing a great reduction in numbers on the 10th day and complete disappearance on the eleventh. The control was still alive after 40 days.

TABLE 5.—BACILLUS LACTIS AEROGENES

Per cent. Honey	Longevity of Culture																
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	11d.	20d.	25d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—
20.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—
30.0	+	+	+	+	+	+	+	+	+	+	+	+	+	—			
40.0	+	+	+	+	+	+	±	—									
50.0	+	+	+	+	±	±	—										
60.0	+	+	+	+	±	—											
70.0	+	+	+	+	±	—											
80.0	+	+	+	+	±	—											
90.0	+	+	+	+	±	—											
100.0	+	+	+	+	+	±	—										

Bacillus lactis aerogenes was present in all concentrations after 24 hours, but showed a very marked reduction in numbers in 48 hours above 40 per cent.; it died out in the pure honey on the fourth day. On the third day it disappeared from the 60, 70, 80, and 90 per cent., and on the fourth, fifth, and eleventh days from the 50 per cent., 40 per cent., and 30 per cent., respectively. Abundant growth was obtained from the control, 10 per cent., and 20 per cent. after 25 days, but in 40 days all were dead but the control.

TABLE 6.—BACILLUS PARATYPHOSUS "B"

Per cent. Honey	Longevity of Culture								
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	40d.
0.0	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	±	—		
20.0	+	+	+	+	+	—			
30.0	+	+	+	+	—				
40.0	+	+	+	—					
50.0	+	+	+	—					
60.0	+	+	±	—					
70.0	+	+	±	—					
80.0	+	+	±	—					
90.0	+	+	±	—					
100.0	+	+	+	+	—				

Bacillus paratyphosus "B" was among the most sensitive organisms studied. After 10 hours its numbers were very much reduced in the 60, 70, 80, and 90 per cent. In 24 hours it had disappeared altogether from dilutions above 30 per cent.; no growth was obtained from the 30 per cent. on the second day, and on the third the organisms had died out in the 20 per cent. and were greatly diminished in the 10 per cent., from which it was absent on the fourth day. The control in salt solution was alive on the fortieth day. It disappeared from the pure honey in 48 hours.

TABLE 7.—BACILLUS COLI COMMUNIS

Per cent. Honey	Longevity of Culture															
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	11d.	12d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	±	±	—	
20.0	+	+	+	+	+	+	+	±	±	—						
30.0	+	+	+	+	+	+	+	—								
40.0	+	+	+	+	+	+	±	—								
50.0	+	+	+	+	+	+	—									
60.0	+	+	+	+	+	+	—									
70.0	+	+	+	+	+	+	—									
80.0	+	+	+	+	+	+	—									
90.0	+	+	+	+	+	+	—									
100.0	+	+	+	+	+	+	±	±	—							

Bacillus coli communis was the most resistant form met with. No harmful action could be noted in any concentration until the fourth day, when the culture was dead in the 50, 60, 70, 80, and

90 per cent. solution. At this time there was also considerable reduction in the 40 per cent. On the fifth day no growth was secured from the 40 and 30 per cent., and the numbers were much less in the 20 per cent.; the latter was sterile on the seventh; the culture was still alive in the 10 per cent. on the eleventh day, but was dead on the twelfth. The control gave good growth still on the fortieth day. It was dead in the pure honey on the sixth day.

TABLE 8.—BACILLUS DYSENTERIAE

Per cent. Honey	Longevity of Culture								
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	25d.	30d.
0.0	+	+	+	+	+	+	+	+	—
10.0	+	+	+	+	+	+	—		
20.0	+	+	+	+	+	±	—		
30.0	+	+	+	+	—				
40.0	+	+	—						
50.0	+	+	—						
60.0	+	+	—						
70.0	+	+	—						
80.0	+	+	—						
90.0	+	+	—						
100.0	+	+	—						

Next to *Bacillus faecalis alkaligenes*, *Bacillus dysenteriae* appears to be the most sensitive to the injurious action of the honey. Ten hours exposure to the 40, 50, 60, 70, 80, and 90 per cent. dilutions, as well as the pure honey, was sufficient to destroy this organism. It died out on the second day in the 30 per cent. and on the fourth day in the 10 and 20 per cent. The control still gave growth after 25 days, but was dead after 30 days.

TABLE 9.—BACILLUS ENTERITIDIS

Per cent. Honey	Longevity of Culture															
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	15d.	25d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—
20.0	+	+	+	+	+	+	±	±	—							
30.0	+	+	+	+	+	+	±	—								
40.0	+	+	+	+	±	—										
50.0	+	+	+	±	—											
60.0	+	+	+	±	—											
70.0	+	+	+	±	—											
80.0	+	+	+	±	—											
90.0	+	+	+	±	—											
100.0	+	+	+	±	—											

Bacillus enteritidis showed the injurious action of the honey after 24 hours in the dilutions above 40 per cent., the same giving no growth in 48 hours. It was dead in the pure honey in 48 hours;

numbers were reduced in the 40 per cent. in 48 hours, and the culture was dead on the third day. On the fourth day the organisms in both the 30 per cent. and 20 per cent. were affected, and they died out in the former on the fifth day and in the latter on the sixth. The bacteria were still active in the 10 per cent. dilution after 25 days, but were dead in 40 days. The control was alive after 40 days.

TABLE 10.—BACILLUS PARATYPHOSUS "A"

Per cent. Honey	Longevity of Culture													
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.	40d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	±	±	—			
20.0	+	+	+	+	+	—								
30.0	+	+	+	+	—									
40.0	+	+	+	—										
50.0	+	+	+	—										
60.0	+	+	+	—										
70.0	+	+	+	—										
80.0	+	+	+	—										
90.0	+	+	+	—										
100.0	+	+	+	—										

Bacillus paratyphosus "A" appears to exhibit about the same degree of injury from the higher concentrations as *B. paratyphosus "B"*. The culture was dead after 24 hours in all dilutions above 30 per cent., including that in the pure honey. It disappeared from the 30 per cent. and 20 per cent. on the second and third days, respectively, and was reduced in numbers in the 10 per cent. by the sixth day, disappearing altogether on the eighth. The control in salt solution was alive after 40 days.

SERIES II.—FALL HONEY SIX MONTHS OLD

A second series of experiments was undertaken with another lot of honey, which differed from the first only in that it had stood six months in an open-top pail and had lost water by evaporation. The acidity of this sample was .09 per cent. computed as formic acid.

TABLE 11.—BACILLUS TYPHOSUS

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	—							
20.0	+	+	+	+	—								
30.0	+	+	+	—									
40.0	+	+	+	—									
50.0	+	+	+	—									
60.0	+	+	—										
70.0	+	+	—										
80.0	+	+	—										
90.0	+	+	—										
100.0	+	+	+	—									

B. typhosus was no longer present in the pure honey after 24 hours, and it was absent from the dilutions above 50 per cent. in 10 hours. After 24 hours it had disappeared from the 30, 40, and 50 per cent. dilutions; after 48 and 72 hours it was no longer present in the 20 and 10 per cent. dilutions, respectively. The control was still alive after 10 days.

TABLE 12.—B. FECALIS ALKALIGENES

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	—										
20.0	+	—											
30.0	+	—											
40.0	+	—											
50.0	+	—											
60.0	+	—											
70.0	+	—											
80.0	+	—											
90.0	+	—											
100.0	+	—											

B. fecalis alkaligenes was even more sensitive to the killing action of the honey here than in the preceding series. After 5 hours it had disappeared from all dilutions except the 10 per cent. and was absent from this after 10 hours. The pure honey was sterile after 5 hours. The control was alive after 10 days.

TABLE 13.—B. PROTEUS VULGARIS

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	+	+	+	+	+	+	+
30.0	+	+	+	+	—								
40.0	+	+	+	—									
50.0	+	+	+	—									
60.0	+	+	+	—									
70.0	+	+	+	—									
80.0	+	+	+	—									
90.0	+	+	+	—									
100.0	+	+	+	+	+	±	—						

B. proteus vulgaris was the most resistant of all the organisms in the lowest concentrations, being present in apparently undiminished numbers in the control, 10, and 20 per cent. after 10 days. It was dead in the pure honey on the fourth day; after 24 hours it had disappeared from all dilutions above the 30 per cent., which was sterile on the second day.

TABLE 14.—B. SUIPESTIFER

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	±	—						
20.0	+	+	+	+	—								
30.0	+	+	+	+	—								
40.0	+	+	+	—									
50.0	+	+	+	—									
60.0	+	+	—										
70.0	+	+	—										
80.0	+	+	—										
90.0	+	+	—										
100.0	+	+	+	+	±	—							

In the pure honey, *B. suipestifer* was still alive on the second day, altho decreased in numbers, but by the third it was dead. In dilutions above 50 per cent. it was dead after 10 hours; it was absent in 24 hours from the 40 and 50 per cent., and in 48 hours it had disappeared from the 20 and 30 per cent. On the third day the numbers were considerably reduced in the 10 per cent., and on the fourth day the solution was sterile. The control was alive after 10 days.

TABLE 15.—B. LACTIS AEROGENES

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	+	+	+	+	+	+	+	+
20.0	+	+	+	+	+	+	±	±	±	±	—		
30.0	+	+	+	+	—								
40.0	+	+	+	—									
50.0	+	+	+	—									
60.0	+	+	±	—									
70.0	+	+	±	—									
80.0	+	+	±	—									
90.0	+	+	±	—									
100.0	+	+	+	+	±	—							

B. lactis aerogenes lived in the pure honey until the third day; however, in 48 hours there was a reduction in numbers. The organisms disappeared rather rapidly from the 60, 70, 80, and 90 per cent. in 10 hours and were absent from all above 30 per cent. in 24 hours. After 48 hours the 30 per cent. gave no growth and by the eighth day the 20 per cent. was sterile; growth was still obtained from the 10 per cent. and control after 10 days.

TABLE 16.—PARATYPHOSUS "B"

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	±	—							
20.0	+	+	+	+	—								
30.0	+	+	—										
40.0	+	+	—										
50.0	+	+	—										
60.0	+	±	—										
70.0	+	±	—										
80.0	+	±	—										
90.0	+	±	—										
100.0	+	+	+	—									

B. paratyphosus "B" behaved almost the same toward the honey as *B. paratyphosus "A"*. The germs were dead in 24 hours in the pure honey; the numbers were much reduced in the 60, 70, 80, and 90 per cent. after 5 hours, and in 10 hours all were dead in the dilutions above 20 per cent. After 48 hours no growth was obtained from the 20 per cent. and there was a very marked reduction in numbers in the 10 per cent.; the latter was sterile on the third day. The control was alive after 10 days.

TABLE 17.—B. COLI COMMUNIS

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	±	±	±	—				
20.0	+	+	+	+	+	±	—						
30.0	+	+	+	+	+	—							
40.0	+	+	+	+	+	—							
50.0	+	+	+	+	±	—							
60.0	+	+	+	+	±	—							
70.0	+	+	+	+	±	—							
80.0	+	+	+	+	±	—							
90.0	+	+	+	+	±	—							
100.0	+	+	+	+	+	±	±	—					

As in the preceding series, *B. coli communis* was the most resistant organism studied so far as the higher concentrations were concerned. It did not die out in the pure honey until the fifth day, altho there was a reduction in numbers on the third day. On the second day there was a reduction in numbers in all concentrations above 40 per cent., while by the third, all were dead above 20 per cent. The 20 per cent. died out by the fourth day, and the 10 per cent. was sterile on the sixth. The control was alive after 10 days.

TABLE 18.—B. DYSENTERIAE

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	±	—										
20.0	+	±	—										
30.0	+	—											
40.0	+	—											
50.0	+	—											
60.0	+	—											
70.0	+	—											
80.0	+	—											
90.0	+	—											
100.0	+	+	—										

B. dysenteriae appeared to be almost as sensitive as *B. fecalis alkaligenes.* It was present in the pure honey after 5 hours, but absent after 10. In 5 hours the organisms had disappeared from all dilutions above the 20 per cent. and the numbers were much reduced in the 10 and 20 per cent.; after 10 hours, these, too, were sterile. The control gave growth after 10 days.

TABLE 19.—B. ENTERITIDIS

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	±	—								
20.0	+	+	+	—									
30.0	+	+	+	—									
40.0	+	+	+	—									
50.0	+	+	+	—									
60.0	+	+	±	—									
70.0	+	+	±	—									
80.0	+	+	±	—									
90.0	+	+	±	—									
100.0	+	+	+	+	±	—							

B. enteritidis was alive in the pure honey on the second day, but its numbers were much less than in the control; it was dead on the third day. There was a marked reduction of the organisms in the 60, 70, 80, and 90 per cent. concentrations in 10 hours, and after 24 hours, the 10 per cent. dilution was the only one which contained living organisms; by the second day they had disappeared from this. The control gave growth after 10 days.

TABLE 20.—B. PARATYPHOSUS "A"

Per cent. Honey	Longevity of Culture												
	0	5 hrs.	10 hrs.	1d.	2d.	3d.	4d.	5d.	6d.	7d.	8d.	9d.	10d.
0.0	+	+	+	+	+	+	+	+	+	+	+	+	+
10.0	+	+	+	+	+	—							
20.0	+	+	+	+	—								
30.0	+	+	—										
40.0	+	+	—										
50.0	+	±	—										
60.0	+	±	—										
70.0	+	±	—										
80.0	+	±	—										
90.0	+	±	—										
100.0	+	+	+	—									

B. paratyphosus "A" was dead in the pure honey after 24 hours. In the dilutions above 40 per cent. the numbers were reduced after 5 hours, and in ten hours everything above 20 per cent. was sterile. By the second day the organisms had disappeared from the 20 per cent., and by the third from the 10 per cent. The control was alive after 10 days.

SUMMARY

The longevity of the typhoid-colon group in honey is very limited.

The failure of the organisms to die out as readily in the concentrated honey as in the dilutions was rather surprising. A possible explanation of this suggests itself in the physical state of the sugar particles in the honey. Assuming the honey to have been a saturated solution, and this appears to have been the case, there is a probability that we had here a colloidal solution with low osmotic pressure. In such a solution, plasmolysis would take place relatively slowly. When water was added, as in the dilutions, some of the colloidal sugar passed over into molecular solution, the osmotic pressure increased and plasmolysis became more active.

B. fecalis alkaligenes succumbs most readily, and *B. coli communis* least so. The other members of the group occupy an intermediate position, increasing in resistance in the higher concentrations in approximately the following order, there being some queston about the relative placing of *B. typhosus, B. enteritidis,* and *B. proteus vulgaris*: *B. dysenteriae, B. paratyphosus "B", B. paratyphosus "A", B. typhosus, B. enteritidis, B. proteus vulgaris, B. suipestifer* and *B. lactis aerogenes.*

The probability of honey acting as a carrier of typhoid fever, dysentery, and varous diarrhoeal affections is very slight.

REFERENCES

[1] White, Gershom Franklin, "The Bacteria of the Apiary". Tech. Series, No. 14, Bu. Entomology, U. S. D. A., Nov., 1906.

[2] White, G. F., "The Cause of European Foul Brood". Circular 157, Bul. Entomology, U. S. D. A., May, 1912.

[3] Phillips, E. F., "Production and Care of Extracted Honey". Bul. 75, Part 1, p. 12, Bu. Entomology, U. S. D. A., Dec., 1907.

[4] Phillips, E. F., "The Treatment of Bee Diseases". Farmer's Bulletin No. 442, p. 12, 1911.

[5] Shutt, "Ripe and Unripe Honey". Experimental Farms Reports, p. 163, 1902. Ottawa, Canada.

[6] Root, H. H., "Beware Fermented Honey". Gleanings in Bee Culture, p. 398, Vol. 46, July, 1918.

[7] Coop, A. J., "Fermentation of Honey; a New Trouble". Gleanings in Bee Culture, p. 1055, Vol. 36, 1908.

[9] Nussbaumer, T., "Honey Fermentation and Some Notes in Regard to the Chemical Composition of Honey". Ztsch. Untusuch, Nahr. u. Genussnitl., 20, No. 5, pp. 272-277, No. 5.

[9] Farnsteiner, K. et al., Ber. Hyg. Inst. Hamburg, p. 70, 1900-1902.

[10] Browne, C. A., "Chemical Analyses and Composition of American Honeys". Bul. 110, Bu. Chemistry, U. S. D. A., 1908.

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Bulletin 253 June, 1920

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

IRRIGATION WATER AS A FACTOR IN THE DISSEMINATION OF WEED SEEDS

By G. E. EGGINTON and W. W. ROBBINS

In the foreground, the grazed ditch bank is free from weeds, while across the fence the ungrazed bank is overgrown with weeds.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

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Irrigation Water as a Factor in the Dissemination of Weed Seed

By G. E. EGGINTON and W. W. ROBBINS

It is well known that there are many different agencies that are responsible for the spread of weed seeds. No other means of introducing weeds is probably so effective as the sale and distribution of impure commercial seeds. Weed seeds are also carried in screenings, in baled hay, in the packing about trees, in feed stuffs; they are taken from place to place in the hair or wool or on the feet of live stock; they are conveyed by birds. Light, winged seeds are often borne long distances by wind. In addition to the above means of seed dispersal, irrigation water is a most important factor in the dissemination of weed seeds in the irrigated sections of the western states. Ditch banks everywhere are densely overgrown with weeds, which shed their seeds in the water, and these are carried down stream, given a good soaking in transit, and planted on a well-soaked soil—all conditions being ideal for germination. In the belief that this was a prolific means of distributing weed seeds, an investigation was begun by this Station to determine the extent of distribution caused in this way. This investigation has just been completed and the results are given herewith.

It is believed that the data herein presented will serve to emphasize the fact that our irrigation waters are conveying tremendous quantities of weed seeds, that our ditch banks are more to be feared than our roadsides as sources of weed infestation, and that it will point to the need of regulations requiring the removal of weeds on ditch banks as well as along roadsides and show the value of grazing ditch banks for the control of weeds upon them.

Germination studies of weed seeds carried in irrigation waters are now under way. The results of these studies will be reported in a later bulletin of the Station.

METHOD

It was deemed advisable at the start to obtain data as to the actual quantities of seeds carried by typical irrigation ditches. For this purpose a cylindrical seed trap of fine copper wire gauze was constructed (Fig.1). It measures 10 inches long and 3¼ inches in diameter. Floats on the side keep the trap partly above the water. The cross section of the water cut is a semi-circle having an area of 3.36 square inches. The trap was made long enough to give a total pore space at least three times the area of the opening, in order that there would be little or no deflection of the water to either side. Of course, in practice it was found that at times when there was much material being carried in the ditches, accumulation of debris in the trap soon reduced the pore space to a point which caused a marked deflection of the current. For example, during the early part of the irrigation season, the ditches are carrying enormous quantities of weed seeds and other material. Then, the seed trap might fill to capacity in fifteen or twenty minutes. On the other hand, during the middle of the irrigating season, a similar seed trap might be left in the ditch for twelve hours without filling to capacity.

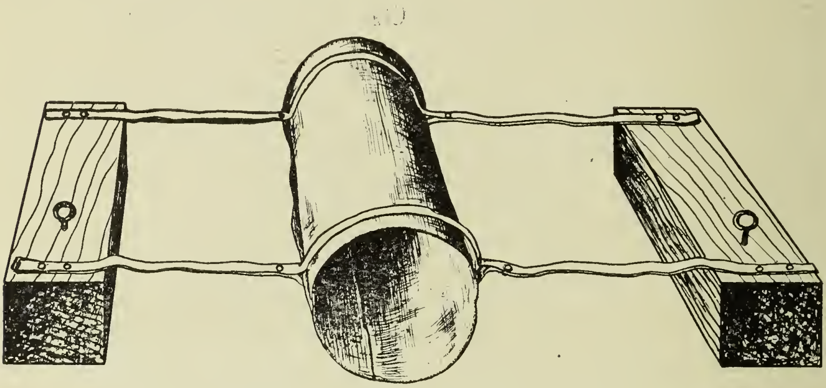

Fig. 1—Seed trap of fine copper wire gauze, used in catching seeds floating on stream surface.

Metal eyes were screwed in the floats, and by means of cords attached to stakes on the ditch banks, the trap was held in mid-stream.

The traps were collected at the end of definite periods, and the seeds and other material washed from them. This process was facilitated by a removable gauze cap at the posterior end of the trap. The "catch" was laid out on glass plates in a dry compartment of the greenhouse and allowed to become thoroughly dry. It was then broken up by hand, spread out on a clean glass plate and worked over to separate out the weed seeds from debris. This tedious work was often made

Traps were set in a number of irrigation ditches in and about Fort Collins, Colorado. These included a large main ditch and several smaller ones. The data collected covered two seasons.

The ditches from which the seed catches were taken are designated as: No. 1 (the Arthur ditch), No. 2, and No. 3, which are laterals from No. 1.

The majority of catches were taken from No. 1 ditch which is, on the average, 12 feet wide, from 4 to 6 feet deep, and about 7 miles long, its source being the Cache la Poudre River two miles southeast of La Porte. The banks are steep and, in places, have been undermined by the current. The bottom of this ditch is covered by a layer of fine, silty mud, ranging in depth from 3 to 14 inches. Ditches No. 2 and No. 3 are 2 to 2½ feet wide; 1 to 3 feet deep, and about 1½ miles long. They have their sources from No. 1 ditch 1 mile apart. The bottoms of these ditches are rather sandy as compared with the bottom of ditch No. 1.

The seed traps were set in No. 1 ditch only when the water was 3 to 4 feet deep, and in No. 2 and No. 3 when the water was 6 inches or more in depth.

The velocity of the current varied from day to day. On those days on which the traps were set, the average velocity was 1 foot per second.

INDIVIDUAL CATCHES OF WEED SEEDS

The following typical cases give the number of species of weed seeds and the number of seeds of each species in individual catches. It will be kept in mind that the cross-section of water cut by the trap was a semi-circle, 3.36 square inches in area.

TEST No. 1. DITCH No. 2.

Date, June 1, 1918. Duration, 60 min.

Species of weed seeds, 7.
Number of seeds, 72.

On pages 13, 14 and 15 will be found common names of the following plants.

Chenopodium album	7
Iva xanthifolia	3
Polygonum aviculare	2
Taraxacum officinale	56
Verbena hastata	2
Ambrosia trifida	1
Leonurus cardiaca	1

TEST No. 2. DITCH No. 3.

Date, June 1, 1918. Duration, 80 min.

Species of weed seeds, 10.
Number of seeds, 35.

Amaranthus blitoides	2
Amaranthus retroflexus	1
Chenopodium album	9
Iva xanthifolia	1
Iva ciliata	1
Polygonum persicaria	1
Rumex crispus	1
Taraxacum officinale	16
Grindelia squarrosa	2
Ambrosia trifida	1

TEST No. 3. DITCH No. 1.

Date, June 1, 1918. Duration, 20 min.

Species of weed seeds, 9.
Number of seeds, 20.

Amaranthus blitoides	5
Amaranthus retroflexus	2
Chenopodium album	1
Polygonum aviculare	1
Polygonum convolvulus	1
Rumex crispus	6
Taraxacum officinale	2
Teucrium occidentale	1
Grindelia squarrosa	1

TEST No. 5. DITCH No. 3.

Date, June 2, 1918. Duration, 180 min.

Species of weed seeds, 14.
Number of seeds, 168.

Amaranthus blitoides	13
Amaranthus retroflexus	5
Chenopodium album	78
Iva xanthifolia	11
Polygonum aviculare	11
Polygonum convolvulus	12
Polygonum persicaria	1
Rumex crispus	6
Taraxacum officinale	12
Teucrium occidentale	15
Grindelia squarrosa	1
Salvia species	1
Ambrosia trifida	1
Franseria tomentosa	1

TEST No. 8. DITCH No. 2.

Date, June 3, 1918. Duration, 180 min.

Species of weed seeds, 16.
Number of seeds, 129.

Salvia species	1
Ambrosia trifida	1
Solanum rostratum	1
Amaranthus blitoides	13
Amaranthus retroflexus	4
Carex species	1
Chenopodium album	21
Iva xanthifolia	10
Iva ciliata	1
Polygonum aviculare	7
Polygonum convolvulus	2
Polygonum persicaria	2
Taraxacum officinale	61
Verbena hastata	2
Ambrosia artemisaefolia	1
Malvastrum coccineum	1

TEST No. 10. DITCH No. 1.

Date, June 3, 1918. Duration, 180 min.

Species of weed seeds, 9.
Number of seeds, 1,039.

Amaranthus blitoides	27
Amaranthus retroflexus	25
Carex species	6
Chenopodium album	22
Iva xanthifolia	16
Polygonum aviculare	9
Rumex crispus	3
Taraxacum officinale	930
Polygonum dumetorum	1

TEST No. 13. DITCH No. 2.

Date, June 5, 1918. Duration, 1,440 min.

Species of weed seeds, 7.
Number of seeds, 64.

Amaranthus blitoides	11
Amaranthus retroflexus	9
Carex species	6
Iva xanthifolia	4
Polygonum aviculare	3
Rumex crispus	1
Taraxacum officinale	30

TEST No. 15. DITCH No. 2.

Date, June 5, 1918. Duration, 1,440 min.

Species of weed seeds, 10.
Number of seeds, 84.

Amaranthus blitoides	7
Carex species	5
Chenopodium album	21
Iva xanthifolia	9
Polygonum aviculare	3
Polygonum convolvulus	2
Rumex crispus	1
Taraxacum officinale	34
Grindelia squarrosa	1
Verbena stricta	1

TEST No. 16. DITCH No. 1.

Date, June 5, 1918. Duration, 1,080 min.

Species of weed seeds, 14.
Number of seeds, 149.

Amaranthus blitoides	13
Amaranthus retroflexus	12
Carex species	18
Chenopodium album	11
Iva xanthifolia	11
Polygonum aviculare	11
Polygonum convolvulus	1
Polygonum persicaria	2
Rumex crispus	1
Taraxacum officinale	65
Grindelia squarrosa	1
Ranunculus species	1
Ambrosia artemisaefolia	1
Echinochloa crus-galli	1

TEST No. 18. DITCH No. 2.

Date, June 6, 1918. Duration, 300 min.

Species of weed seeds, 13.
Number of seeds, 173.

Amaranthus blitoides	17
Carex species	9
Chenopodium album	21
Iva xanthifolia	7
Polygonum aviculare	10
Polygonum convolvulus	1
Polygonum persicaria	3
Rumex crispus	4
Ambrosia trifida	2
Taraxacum officinale	96
Echinochloa crus-galli	1
Nepeta cataria	1
Grindelia squarrosa	1

TEST No. 20. DITCH No. 2.

Date, June 7, 1918. Duration, 300 min.

Species of weed seeds, 12.
Number of seeds, 229.

Amaranthus blitoides	35
Amaranthus retroflexus	27
Carex species	46
Chenopodium album	56
Iva xanthifolia	8
Polygonum aviculare	20
Polygonum convolvulus	4
Rumex crispus	14
Taraxacum officinale	16
Grindelia squarrosa	1
Ranunculus species	1
Cleome serrulata	1

TEST No. 25. DITCH No. 2.

Date, June 8, 1918. Duration, 720 min.

Species of weed seeds, 11.
Number of seeds, 257.

Amaranthus blitoides	18
Amaranthus retroflexus	16
Carex species	28
Chenopodium album	33
Iva xanthifolia	1
Polygonum aviculare	15
Polygonum convolvulus	2
Polygonum persicaria	3
Rumex crispus	3
Taraxacum officinale	137
Argemone intermedia	1

TEST No. 29. DITCH No. 1.

Date, June 11, 1918. Duration, 360 min.

Species of weed seeds, 10.
Number of seeds, 199.

Amaranthus blitoides	7
Amaranthus retroflexus	17
Carex species	85
Chenopodium album	30
Iva xanthifolia	6
Polygonum aviculare	10
Polygonum persicaria	2
Taraxacum officinale	40
Verbena hastata	1
Panicum capillare	1

TEST No. 30. DITCH No. 2.

Date, June 11, 1918. Duration, 360 min.

Species of weed seeds, 5.
Number of seeds, 16.

Amaranthus retroflexus	2
Carex species	5
Chenopodium album	7
Rumex crispus	1
Taraxacum officinale	1

TEST No. 32. DITCH No. 2.

Date, June 11, 1918. Duration, 360 min.

Species of weed seeds, 18.
Number of seeds, 633.

Amaranthus blitoides	29
Amaranthus retroflexus	50
Carex species	208
Chenopodium album	235
Iva xanthifolia	15
Polygonum aviculare	21
Polygonum convolvulus	3
Polygonum persicaria	4
Rumex crispus	11
Taraxacum officinale	33
Grindelia squarrosa	4
Cleome serrulata	2
Ambrosia artemisaefolia	1
Panicum capillare	2
Nepeta cataria	4
Geranium species	4
Portulaca oleracea	7
Glyceria species	2

TEST No. 34. DITCH No. 2.

Date, June 12, 1918. Duration, 360 min.

Species of weed seeds, 14.
Number of seeds, 185.

Amaranthus blitoides	23
Amaranthus retroflexus	55
Carex species	2
Chenopodium album	67
Iva xanthifolia	6
Polygonum aviculare	11
Polygonum convolvulus	5
Polygonum persicaria	1
Rumex crispus	6
Taraxacum officinale	4
Nepeta cataria	1
Oxalis stricta	1
Syntherisma humifusum	2
Lupinus species	1

TEST No. 38. DITCH No. 2

Date, June 21, 1918. Duration, 240 min.

Species of weed seeds, 15.
Number of seeds, 331.

Amaranthus blitoides	26
Amaranthus retroflexus	57
Ambrosia artemisaefolia	1
Carex species	110
Chenopodium album	85
Echinochloa crus-galli	1
Iva xanthifolia	7
Polygonum aviculare	12
Polygonum convolvulus	2
Polygonum persicaria	1
Portulaca oleracea	15
Ranunculus species	1
Taraxacum officinale	3
Verbena hastata	4
Grindelia squarrosa	6

TEST No. 40. DITCH No. 2.

Date, June 18, 1918. Duration, 300 min.

Species of weed seeds, 16.
Number of seeds, 266.

Amaranthus blitoides	31
Amaranthus retroflexus	31
Carex species	90
Chenopodium album	67
Grindelia squarrosa	3
Iva xanthifolia	5
Nepeta cataria	2
Polygonum aviculare	12
Polygonum convolvulus	1
Polygonum persicaria	1
Portulaca oleracea	10
Rumex crispus	1
Taraxacum officinale	2
Verbena hastata	8
Polygonum engelmanii	1
Capsella bursa-pastoris	1

TEST No. 41. DITCH No. 2.

Date, June 21, 1918. Duration, 360 min.

Species of weed seeds, 16.
Number of seeds, 863.

Amaranthus blitoides	85
Amaranthus retroflexus	158
Carex species	365
Chenopodium album	170
Ambrosia trifida	1
Cleome serrulata	1
Grindelia squarrosa	1
Iva xanthifolia	39
Polygonum aviculare	30
Polygonum convolvulus	9
Polygonum persicaria	4
Rumex crispus	7
Taraxacum officinale	8
Verbena hastata	3
Capsella bursa-pastoris	3
Avena sativa	6

TEST No. 42. DITCH No. 2.

Date, June 19, 1918. Duration, 420 min.

Species of weed seeds, 24.
Number of seeds, 1,364.

Amaranthus blitoides	69
Amaranthus retroflexus	238
Carex species	655
Chenopodium album	230
Cleome serrulata	1
Geranium species	5
Grindelia squarrosa	9
Helianthus annuus	2
Iva xanthifolia	23
Oxalis stricta	1
Polygonum aviculare	27
Polygonum convolvulus	10
Polygonum persicaria	8
Portulaca oleracea	23
Rumex acetosella	1
Rumex crispus	16
Salvia species	3
Solanum rostratum	3
Taraxacum officinale	22
Verbena hastata	3
Capsella bursa-pastoris	1
Medicago lupulina	1
Veronica species	1
Avena sativa	12

TEST No. 43. DITCH No. 1.

Date, June 19, 1918. Duration, 420 min.

Species of weed seeds, 20.
Number of seeds, 763.

Amaranthus blitoides	28
Amaranthus retroflexus	22
Carex species	542
Chenopodium album	73
Ambroisa trifida	1
Geranium species	1
Grindelia squarrosa	2
Helianthus annuus	1
Iva xanthifolia	23
Polygonum aviculare	30
Polygonum convolvulus	9
Polygonum persicaria	2
Ranunculus species	1
Rumex crispus	9
Setaria viridis	3
Solanum rostratum	1
Taraxacum officinale	8
Teucrium occidentale	1
Urtica gracilis	1
Avena sativa	1

TEST No. 47. DITCH No. 2

Date, June 20, 1918. Duration, 240 min.

Species of weed seeds, 13.
Number of seeds, 299.

Amaranthus blitoides	21
Amaranthus retroflexus	21
Carex species	174

Chenopodium album	40
Grindelia squarrosa	2
Iva xanthifolia	13
Polygonum aviculare	14
Polygonum convolvulus	4
Rumex acetosella	3
Cleome serrulata	1
Taraxacum officinale	4
Teucrium occidentale	1
Polygonum engelmanii	1

TEST No. 54. DITCH No. 1.

Date, June 26, 1918. Duration, 360 min.

Species of weed seeds, 4.
Number of seeds, 16.

Amaranthus retroflexus	2
Carex species	4
Chenopodium album	5
Polygonum aviculare	5

TEST No. 57. DITCH No. 2.

Date, June 26, 1918. Duration, 360 min.

Species of weed seeds, 16.
Number of seeds, 518.

Amaranthus blitoides	46
Amaranthus retroflexus	111
Carex species	51
Chenopodium album	107
Iva xanthifolia	2
Polygonum aviculare	19
Polygonum convolvulus	14
Polygonum persicaria	2
Geranium species	3
Portulaca oleracea	4
Rumex crispus	5
Taraxacum officinale	2
Urtica gracilis	3
Verbena hastata	145
Polygonum engelmanii	1
Lappula occidentale	3

TEST No. 62. DITCH No. 1.

Date, July 2, 1918. Duration, 360 min.

Species of weed seeds, 23.
Number of seeds, 377.

Amaranthus blitoides	47
Amaranthus retroflexus	108
Carex species	41
Chenopodium album	82
Iva xanthifolia	7
Polygonum aviculare	31
Polygonum convolvulus	2
Polygonum persicaria	4
Rumex crispus	5
Stellaria media	3
Taraxacum officinale	5
Teucrium occidentale	1
Grindelia squarrosa	4
Urtica gracilis	3
Verbena hastata	18
Ranunculus species	2
Solanum rostratum	1
Helianthus annuus	1
Geranium species	3
Portulaca oleracea	3
Polygonum engelmanii	2
Capsella bursa-pastoris	3
Avena sativa	1

TEST No. 71. DITCH No. 1.

Date, July 30, 1918. Duration, 1,080 min.

Species of weed seeds, 6.
Number of seeds, 24.

Amaranthus blitoides	5
Chenopodium album	5
Grindelia squarrosa	1
Iva xanthifolia	1
Polygonum aviculare	4
Rumex crispus	8

TEST No. 72. DITCH No. 1.

Date, Aug. 13, 1918. Duration, 1,440 min.

Species of weed seeds, 6.
Number of seeds, 18.

Amaranthus blitoides	4
Amaranthus retroflexus	1
Polygonum aviculare	4
Polygonum convolvulus	4
Rumex crispus	4
Sonchus asper	1

TEST No. 74. DITCH No. 1.

Date, July 29, 1918. Duration, 480 min.

Species of weed seeds, 3.
Number of seeds, 3.

Amaranthus blitoides	1
Carex species	1
Polygonum aviculare	1

TEST No. 75. DITCH No. 1.

Date, July 31, 1918. Duration, 1,440 min.

Species of weed seeds, 2.
Number of seeds, 2.

Amaranthus blitoides	1
Rumex crispus	1

TEST No. 76. DITCH No. 3.

Date, July 26, 1918. Duration, 1,440 min.

Species of weed seeds, 6.
Number of seeds, 7.

Amaranthus retroflexus	1
Chenopodium album	2
Rumex crispus	1
Ambrosia trifida	1
Iva xanthifolia	1
Verbena hastata	1

TEST No. 77. DITCH No. 1.
Date, Aug. 1, 1918. Duration, 1,440 min.

Species of weed seeds, 3.
Number of seeds, 3.

Amaranthus blitoides	1
Carex species	1
Rumex crispus	1

TEST No. 79. DITCH No. 1.
Date, July 22, 1918. Duration, 360 min.

Species of weed seeds, 2.
Number of seeds, 2.

Rumex crispus	1
Secale cereale	1

TEST No. 81. DITCH No. 1.
Date, Aug. 1, 1918. Duration, 1,440 min.

Species of weed seeds, 3.
Number of seeds, 4.

Amaranthus blitoides	2
Rumex crispus	1
Agropyron tenerum	1

TEST No. 86. DITCH No. 1.
Date, July 25, 1918. Duration, 600 min.

Species of weed seeds, 3.
Number of seeds, 4.

Amaranthus retroflexus	1
Chenopodium album	2
Polygonum aviculare	1

TEST No. 90. DITCH No. 1.
Date, July 23, 1918. Duration, 1,080 min.

Species of weed seeds, 2.
Number of seeds, 2.

Amaranthus blitoides	1
Rumex crispus	1

TEST No. 91. DITCH No. 1.
Date, July 25, 1918. Duration, 600 min.

Species of weed seeds, 2.
Number of seeds, 2.

Polygonum convolvulus	1
Rumex crispus	1

TEST No. 96. DITCH No. 1.
Date, Aug. 22, 1918. Duration, 4,320 min.

Species of weed seeds, 3.
Number of seeds, 4.

Ranunculus species	1
Amaranthus blitoides	2
Polygonum aviculare	1

TEST No. 100. DITCH No. 1.
Date, Aug. 10, 1918. Duration, 2,880 min.

Species of weed seeds, 3.
Number of seeds, 13.

Amaranthus blitoides	4
Rumex crispus	6
Polygonum aviculare	7

TEST No. 101. DITCH No. 1.
Date, Aug. 3, 1918. Duration, 1,440 min.

Species of weed seeds, 7.
Number of seeds, 48.

Amaranthus blitoides	16
Amaranthus retroflexus	6
Chenopodium album	7
Polygonum aviculare	8
Rumex crispus	8
Solanum rostratum	1
Ranunculus species	2

TEST No. 106. DITCH No. 1.
Date, Aug. 10, 1918. Duration, 720 min.

Species of weed seeds, 7.
Number of seeds, 30.

Carex species	1
Chenopodium album	4
Polygonum aviculare	7
Amaranthus blitoides	8
Polygonum convolvulus	1
Rumex crispus	10
Polygonum engelmanii	1

TEST No. 107. DITCH No. 1.
Date, Aug. 14, 1918. Duration, 1,440 min.

Species of weed seeds, 7.
Number of seeds, 23.

Amaranthus blitoides	4
Amaranthus retroflexus	1
Carex species	2
Chenopodium album	2
Polygonum aviculare	4
Rumex species	9
Geranium species	1

TEST No. 110. DITCH No. 1.
Date, June 5, 1919. Duration, 15 min.

Species of weed seeds, 15.
Number of seeds, 191.

Taraxacum officinale	20
Chenopodium album	23
Carex species	27
Amaranthus blitoides	27
Amaranthus retroflexus	38
Iva xanthifolia	15
Polygonum aviculare	22
Papaver species	3
Grindelia squarrosa	3
Rumex crispus	3
Verbena stricta	1
Leonurus cardiaca	1
Polygonum convolvulus	1
Cleome serrulata	1
Solanum rostratum	1

TEST No. 114. DITCH No. 1.
Date, June 5, 1919. Duration, 15 min.

Species of weed seeds, 18.
Number of seeds, 310.

Taraxacum officinale	30
Carex species	77
Amaranthus blitoides	51

Amaranthus retroflexus	49
Iva xanthifolia	42
Polygonum aviculare	22
Chenopodium album	22
Rumex crispus	6
Helianthus annuus	2
Ambrosia artemisaefolia	3
Grindelia squarrosa	3
Argemone intermedia	1
Solanum rostratum	1
Papaver species	1
Polygonum persicaria	1
Verbena bracteosa	2
Leonurus cardiaca	3
Mentha species	4

TEST No. 118. DITCH No. 1.

Date, May 5, 1916. Duration, 15 min.

Species of weed seeds, 17.
Number of seeds, 99.

Taraxacum officinale	27
Chenopodium album	24
Amaranthus blitoides	4
Amaranthus retroflexus	7
Amaranthus graecizans	1
Iva xanthifolia	4
Rumex crispus	8
Polygonum aviculare	9
Polygonum convolvulus	5
Polygonum persicaria	1
Cleome serrulata	1
Solanum rostratum	1
Ambrosia artemisaefolia	2
Setaria viridis	2
Lappula occidentale	1
Verbena hastata	1
Mentha species	1

TEST No. 121. DITCH No. 1

Date, May 19, 1919. Duration, 15 min.

Species of weed seeds, 21.
Number of seeds, 208.

Taraxacum officinale	6
Amaranthus blitoides	20
Amaranthus retroflexus	41
Rumex crispus	12
Chenopodium album	30
Polygonum aviculare	25
Polygonum convolvulus	7
Polygonum persicaria	3
Ambrosia artemisaefolia	4
Iva xanthifolia	23
Carex species	3
Echinochloa crus-galli	6
Setaria viridis	3
Papaver species	8
Cleome serrulata	1
Grindelia squarrosa	1
Mentha species	4
Verbena bracteosa	8
Helianthus annuus	1
Leonurus cardiaca	1
Panicularia grandis	1

TEST No. 123. DITCH No. 1.

Date, May 20, 1919. Duration, 15 min.

Species of weed seeds, 18.
Number of seeds, 189.

Taraxacum officinale	6
Rumex crispus	5
Chenopodium album	30
Amaranthus retroflexus	57
Amaranthus blitoides	16
Polygonum aviculare	25
Iva xanthifolia	16
Carex species	3
Verbena bracteosa	9
Polygonum convolvulus	4
Papaver species	6
Polygonum persicaria	3
Echinochloa crus-galli	2
Mentha species	3
Argemone intermedia	1
Syntherisma humifusum	1
Solanum rostratum	1
Grindelia squarrosa	1

TEST No. 124. DITCH No. 1.

Date, May 20, 1919. Duration, 15 min.

Species of weed seeds, 20.
Number of seeds, 191.

Taraxacum officinale	34
Amaranthus blitoides	20
Amaranthus retroflexus	28
Chenopodium album	41
Iva xanthifolia	12
Polygonum aviculare	16
Polygonum convolvulus	3
Polygonum persicaria	3
Rumex crispus	5
Carex species	4
Grindelia squarrosa	5
Papaver species	7
Ambrosia artemisaefolia	2
Verbena bracteosa	4
Solanum rostratum	1
Echinochloa crus-galli	1
Setaria viridis	1
Leonurus cardiaca	1
Mentha species	2
Helianthus annuus	1

TEST No. 126. DITCH No. 1.

Date, May 20, 1919. Duration, 15 min.

Species of weed seeds, 20.
Number of seeds, 192.

Taraxacum officinale	18
Chenopodium album	28
Amaranthus blitoides	22
Amaranthus retroflexus	39
Iva xanthifolia	32
Polygonum aviculare	16
Rumex crispus	8
Polygonum convolvulus	3
Polygonum persicaria	5
Echinochloa crus-galli	3
Grindelia squarrosa	2

Papaver species	3
Malvastrum coccineum	2
Verbena bracteosa	2
Salvia lanceolata	1
Atriplex truncata	1
Mentha species	4
Leonurus cardiaca	1
Setaria viridis	1
Carex species	1

TEST No. 133. DITCH No. 1.

Date, May 22, 1919. Duration, 15 min.

Species of weed seeds, 11.
Number of seeds, 208.

Taraxacum officinale	158
Chenopodium album	22
Amaranthus blitoides	10
Amaranthus retroflexus	7
Polygonum aviculare	4
Ambrosia artemisaefolia	1
Iva xanthifolia	1
Rumex crispus	2
Setaria viridis	1
Verbena bracteosa	1
Lepidium apetalum	1

TEST No. 136. DITCH No. 1.

Date, May 23, 1919. Duration, 10 min.

Species of weed seeds, 14.
Number of seeds, 69.

Taraxacum officinale	1
Amaranthus blitoides	15
Amaranthus retroflexus	5
Chenopodium album	13
Iva xanthifolia	8
Polygonum aviculare	9
Polygonum persicaria	2
Papaver species	5
Polygonum convolvulus	3
Rumex crispus	1
Grindelia squarrosa	1
Verbena bracteosa	3
Setaria viridis	2
Melilotus alba	1

TEST No. 137. DITCH No. 1.

Date, May 23, 1919. Duration, 15 min.

Species of weed seeds, 14.
Number of seeds, 287.

Taraxacum officinale	174
Chenopodium album	26
Amaranthus blitoides	7
Amaranthus retroflexus	39
Iva xanthifolia	13
Polygonum aviculare	12
Carex species	4
Polygonum persicaria	3
Polygonum convolvulus	1
Solanum rostratum	1
Verbena bracteosa	3
Rumex crispus	1
Grindelia squarrosa	2
Papaver species	1

TEST No. 140. DITCH No. 1.

Date, May 24, 1919. Duration, 15 min.

Species of weed seeds, 16.
Number of seeds, 213.

Taraxacum officinale	3
Chenopodium album	58
Amaranthus retroflexus	51
Amaranthus blitoides	44
Iva xanthifolia	12
Polygonum aviculare	19
Polygonum convolvulus	2
Papaver species	8
Panicularia grandis	1
Mentha species	2
Verbena bracteosa	5
Teucrium occidentale	1
Setaria viridis	2
Carex species	1
Helianthus annuus	2
Bidens frondosa	1

TEST No. 141. DITCH No. 1.

Date, May 24, 1919. Duration, 15 min.

Species of weed seeds, 17.
Number of seeds, 391.

Taraxacum officinale	245
Amaranthus blitoides	28
Amaranthus retroflexus	34
Chenopodium album	38
Polygonum aviculare	23
Polygonum persicaria	1
Iva xanthifolia	5
Polygonum convolvulus	2
Verbena bracteosa	3
Rumex crispus	2
Ambrosia trifida	1
Cleome serrulata	1
Carex species	4
Papaver species	1
Melilotus alba	1
Grindelia squarrosa	1
Mentha species	1

TEST No. 144. DITCH No. 1.

Date, May 24, 1919. Duration, 15 min.

Species of weed seeds, 16.
Number of seeds, 748.

Taraxacum officinale	461
Chenopodium album	64
Amaranthus retroflexus	63
Amaranthus blitoides	73
Polygonum aviculare	59
Iva xanthifolia	5
Polygonum convolvulus	4
Sonchus asper	7
Rumex crispus	6
Cleome serrulata	2
Polygonum persicaria	1
Verbena bracteosa	2
Argemone intermedia	1
Malvastrum coccineum	1
Ambrosia artemisaefolia	1
Grindelia squarrosa	1

TEST No. 149. DITCH No. 1.

Date, May 27, 1919. Duration, 15 min.

Species of weed seeds, 17.

Number of seeds, 302.

Taraxacum officinale	171
Chenopodium album	47
Amaranthus retroflexus	30
Amaranthus blitoides	14
Polygonum aviculare	15
Iva xanthifolia	7
Rumex crispus	4
Polygonum convolvulus	2
Papaver species	2
Grindelia squarrosa	1
Setaria viridis	2
Verbena bracteosa	2
Mentha species	2
Argemone intermedia	1
Leonurus cardiaca	2

TEST No. 152. DITCH No. 1.

Date, May 27, 1919. Duration, 15 min.

Species of weed seeds, 17.

Number of seeds, 222.

Taraxacum officinale	121
Amaranthus blitoides	17
Amaranthus retroflexus	16
Chenopodium album	27
Polygonum aviculare	11
Iva xanthifolia	7
Polygonum convolvulus	4
Papaver species	4
Rumex crispus	4
Setaria viridis	2
Verbena bracteosa	2
Helianthus annuus	2
Echinochloa crus-galli	1
Polygonum persicaria	1
Mentha species	1
Carex species	1
Cleome serrulata	1

TABLE I.—FREQUENCY OF DIFFERENT SPECIES OF WEED SEEDS IN 156 DITCH SAMPLES

Species—	No. of samples in which occurred
Agropyron tenerum—Slender wheat grass	6
Alopecurus aristulatus—Wolftail	2
Amaranthus blitoides—Prostrate pigweed	138
Amaranthus graecizans—Tumble weed	3
Amaranthus retroflexus—Tall pigweed	131
Ambrosia artemisaefolia—Ragweed	21
Ambrosia trifida—Giant ragweed	19
Arenaria species—Sandwort	4
Argemone intermedia—White prickly poppy	13
Atriplex truncata—Salt bush	1
Avena fatua—Wild oats	1
Bidens frondosa—Beggar ticks	1
Brassica juncea—Indian mustard	1
Brassica nigra—Black mustard	1
Bromus inermis—Brome grass	2
Capsella bursa-pastoris—Shepherd's purse	6
Carex species—Sedge	99
Cleome serrulata—Rocky Mountain bee plant	25
Chenopodium album—Lamb's quarter	131
Echinochloa crus-galli—Barnyard grass	17
Euphorbia marginata—Snow-on-the-mountain	1
Franseria tomentosa—Poverty weed	1
Galium aparine—Cleavers	2
Geranium species—Geranium	15
Glyceria species—Manna grass	1
Grindelia squarrosa—Gumweed	60

Species—	No. of samples in which occurred
Helianthus petiolaris—Sunflower	16
Iva ciliata—Rough marsh elder	2
Iva xanthifolia—Marsh elder	105
Kochia scoparia—Fireweed or burning bush	1
Lactuca scariola—Wild lettuce	1
Lappula occidentale—Beggar's lice	6
Leonurus cardiaca—Motherwort	16
Lepidium apetalum—Peppergrass	2
Lupinus species—Lupine	2
Lycopus americanus—Water horehound	1
Malvastrum coccineum—False mallow	5
Medicago lupulina—Black medick	1
Melilotus alba—White sweet clover	2
Mentha species—Mint	17
Nepeta cataria—Catnip	8
Opuntia polycantha—Prickly pear	1
Oxalis stricta—Wood sorrel	3
Papaver species—Poppy	32
Panicum capillare—Witchgrass	3
Panicularia grandis—Manna grass	3
Polygonum aviculare—Knotweed	133
Polygonum convolvulus—Wild buckwheat	88
Polygonum dumetorum—Smartweed	1
Polygonum engelmanii—Smartweed	12
Polygonum pennsylvanicum—Pennsylvania smartweed	1
Polygonum persicaria—Lady's thumb	70
Portulaca oleracea—Purslane	14
Potentilla monspeliensis—Cinquefoil	2
Ranunculus species—Buttercup	23
Rosa species—Wild rose	1
Rumex acetosella—Sheep sorrel	7
Rumex crispus—Curled dock	122
Salsola tragus—Russian thistle	1
Salvia species—Sage	4
Salvia lanceolata—Sage	4
Setaria glauca—Yellow foxtail	2
Setaria viridis—Green foxtail	20
Solanum rostratum—Buffalo bur	28
Solanum species—Wild potato	2
Sonchus asper—Rough sow thistle	3
Stellaria media—Chickweed	2
Syntherisma humifusum—Small crabgrass	3
Taraxacum officinale—Dandelion	104
Teucrium occidentale—Wood sage	12
Thalictrum species—Meadow-rue	1
Tragopogon sp.—Oyster plant	1
Urtica gracilis—Slender nettle	11
Verbena hastata—Blue vervain	25

Species—	No. of samples in which occurred
Verbena stricta—Hoary vervain	6
Verbena bracteosa—Bracted vervain	34
Verbena bipinnatifida—Bipinnate vervain	1
Veronica species—Speedwell	1
Avena sativa—Oats	11
Secale cereale—Rye	2
Andropogon sorghum—Amber cane	1

From the above table it will be seen that the weed seeds most frequently met with in the irrigation waters examined are:

Prostrate pigweed *(Amaranthus blitoides)*.
Tall pigweed *(Amaranthus retroflexus)*.
Sedge *(Carex sp.)*.
Lamb's quarters *(Chenopodium album)*.
Tall marsh elder *(Iva xanthifolia)*.
Door-weed *(Polygonum aviculare)*.
Black bindweed *(Polygonum convolvulus)*.
Curled dock *(Rumex crispus)*.
Dandelion *(Taraxacum officinale)*.

TABLE II.—SHOWING THE ESTIMATED NUMBER OF SEEDS, OF A FEW REPRESENTATIVE SPECIES, WHICH PASSED A GIVEN POINT ON A 12-FOOT DITCH DURING A PERIOD OF 24 HOURS

KIND OF SEED	Caught on 3¼″ surface Cross-section 4.14 Sq. In.	Time	Floating on 12′ surface Cross-section 234.00 Sq. In.	Time	Date
Dandelion (Taraxacum officinale)	461	15 min.	10,355,904	24 hrs.	5/24/19
Lamb's quarters (Chenopodium album)	58	15 min.	1,302,912	24 hrs.	5/24/19
Pigweed (Amaranthus retroflexus)	57	15 min.	1,280,448	24 hrs.	5/20/19
Wild buckwheat or field bindweed (Polygonum convolvulus)	4	15 min.	89,856	24 hrs.	5/20/19
Curled dock (Rumex crispus)	6	15 min.	134,785	24 hrs.	5/24/19
Marsh elder (Iva xanthifolia)	7	15 min.	157,248	24 hrs.	5/22/19
Green foxtail (Setaria viridis)	2	15 min.	44,928	24 hrs.	5/22/19
Sunflower, wild (Helianthus petiolaris)	2	15 min.	44,928	24 hrs.	5/24/19

The examples cited in the above table do not represent the largest catch of any one species in a 15-minute period.

TABLE III.—SHOWING TOTAL NUMBER OF ALL SPECIES PASSING A GIVEN POINT ON A 12-FOOT DITCH DURING A PERIOD OF 24 HOURS

No. of Species	No. of Seeds Caught in 15 Minutes on a Surface of 3¼″. Cross-section 4.14″. sq. inches	No. of Seeds Passing a Given Point in 24 Hours on a 12 foot Surface. Cross-section, 234 sq. inches	Dates
15	191	4,290,624	6/ 5/1919
18	310	6,963,840	6/ 5/1919
17	99	2,223,936	5/17/1919
21	208	4,672,512	5/19/1919
18	189	4,245,696	5/20/1919
20	191	4,290,624	5/20/1919
11	210	4,717,440	5/22/1919
14	69	1,550,016	5/23/1919
16	213	4,384,832	5/24/1919
17	391	8,783,424	5/24/1919

These estimates are based on 15-minute catches and represent a few of the average samples.

The following ten samples of soil from Ditch No. 1 were taken in late October. The samples were from the bottom and sides, and each contained 36 cubic inches of soil.

TABLE IV.—SEEDS IN MUD OF DITCH

Sample No. 1

Species of weeds—	No. of seeds
Iva xanthifolia	1
Polygonum persicaria	1
Amaranthus blitoides	2
Amaranthus retroflexus	3
Chenopodium album	1

Sample No. 2

Amaranthus retroflexus	2
Chenopodium album	2
Polygonum persicaria	1
Rumex crispus	1

Sample No. 3

Amaranthus blitoides	5
Amaranthus retroflexus	4
Chenopodium album	5
Echinochloa crus-galli	4
Polygonum aviculare	4
Polygonum convolvulus	2
Rumex crispus	9

Sample No. 4

Amaranthus blitoides	2
Chenopodium album	1
Polygonum convolvulus	1

Sample No. 5

Amaranthus blitoides	5
Amaranthus retroflexus	4
Carex sp.	1
Chenopodium album	4
Polygonum aviculare	6
Polygonum persicaria	1
Tragopogon sp.	1

Sample No. 6

Species of weeds—	No. of seeds
Amaranthus blitoides	2
Amaranthus retroflexus	3
Iva xanthifolia	35
Polygonum aviculare	2
Rumex crispus	2
Taraxacum officinale	1

Sample No. 7

Amaranthus blitoides	5
Amaranthus retroflexus	6
Polygonum convolvulus	4
Polygonum aviculare	2
Carex sp.	1
Chenopodium album	4
Portulaca oleracea	1

Sample No. 8

Polygonum convolvulus	2
Polygonum aviculare	1
Carex sp.	1
Chenopodium album	3
Portulaca oleracea	3
Amaranthus blitoides	4
Amaranthus retroflexus	10

Sample No. 9

Rumex crispus	19
Chenopodium album	3
Amaranthus blitoides	2
Polygonum convolvulus	4
Melilotus alba	3
Iva xanthifolia	1

Sample No. 10

Rumex crispus	19
Hordeum jubatum	63
Amaranthus blitoides	2
Amaranthus retroflexus	1
Melilotus alba	1
Polygonum convolvulus	1

TABLE V.—SINKING OF SEEDS WITH AND WITHOUT AGITATION

KIND OF WEED	Number which sank at start		Sank after 15 minutes		Sank after 30 minutes		Sank after 1 hour		Sank after 10 hours		Sank after 20 hours		Sank after 30 hours		Sank after 60 hours		Sank after 100 hours		Sank after 130 hours	
	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation	Without Agitation	With Agitation
Abutilon abutilon	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Amaranthus retroflexus	0	97	0	97	0	97	0	99	0	100	0	100	0	100	0	100	0	100	2	...
Ambrosia artemisaefolia	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Ambrosia trifida	0	0	0	0	0	0	0	7	0	7	0	85	0	90	0	99	0	99	0	...
Brassica arvensis	3	...	5	...	12	...	23	...	42	...	42	...	42	...	47	...	47	...	48	...
Brassica juncea	0	100	0	100	0	100	0	100	3	100	3	100	3	100	12	100	13	100	36	100
Brassica nigra	0	...	0	...	0	...	0	...	0	...	0	...	0	...	2	...	2	...	2	...
Camelina sativa	0	...	89	...	89	...	89	...	89	...	89	...	89	...	89	...	89	...	89	...
Conringia orientalis	1	100	3	100	31	100	51	100	65	100	65	100	66	100	66	100	67	100	68	...
Datura stramonium	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Gaura parviflora	0	4	0	4	0	4	0	4	0	...	0	...	0	...	0	...	0	...	0	...
Helianthus petriolaris	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Iva xanthifolia	0	0	0	0	0	0	0	2	0	10	0	...	0	97	0	97	0	100	0	...
Lactuca scariola	0	2	0	...	0	...	0	...	3	...	5	...	6	...	27	...	28	...	28	...
Lappula occidentale	0	2	0	2	0	2	0	14	0	94	0	100	0	100	2	100	6	100	6	...
Panicum capillare	0	0	0	0	0	0	0	3	0	7	0	23	0	50	0	79	0	...	0	...
Polygonum persicaria	0	54	0	54	0	54	0	54	0	74	0	92	0	96	0	98	0	...	0	...
Salvia lanceolata	0	...	1	...	1	...	1	...	91	...	91	...	91	...	91	...	92	...	92	...
Saponaria vaccaria	16	...	21	...	21	...	21	...	22	...	22	...	22	...	22	...	22	...	23	...
Sonchus oleraceus	0	0	0	0	0	0	0	17	0	99	0	100	0	100	1	100	3	100	3	...
Portulaca oleracea	0	21	0	21	0	0	0	36	0	55	0	67	0	77	0	89	0	93	0	...
Sophia incisa	0	...	0	...	0	...	36	...	57	...	59	...	65	...	85	...	91	...	91	...
Cuscuta planiflora	0	...	0	...	0	...	0	...	0	...	6	...	70	...	70	...	100	...	100	...
Thlaspi arvense	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	...
Chenopodium album	0	9	0	9	0	9	0	10	0	...	0	...	0	...	0	...	6	...	6	...
Kochia scoparia	0	...	0	...	0	...	0	...	0	...	0	...	0	...	12	...	75	...	85	...
Polygonum convolvulus	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	4	...	6	...
Carduus arvensis	0	18	0	18	0	18	0	54	0	78	0	85	0	88	0	95	20	...	20	...
Plantago lanceolata	0	...	0	...	0	...	0	...	0	...	4	...	4	...	6	...	8	...	65	...
Plantago major	0	100	0	100	0	100	44	100	48	100	76	100	76	100	82	100	89	100	90	...
Echinochloa crus-galli	0	...	0	...	0	...	0	...	0	...	0	...	0	...	6	...	6	...	6	...
Capsella bursa-pastoris	0	100	0	100	0	100	41	100	57	100	68	100	69	100	75	100	94	...	94	...
Setaria glauca	0	0	0	0	0	0	0	0	0	5	0	...	0	...	0	...	1	...	4	...
Polanisia trachysperma	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Setaria viridis	0	25	0	25	0	25	0	49	0	65	0	90	0	98	3	98	5	100	6	...
Malva rotundifolia	0	90	1	90	1	90	1	95	1	98	2	99	2	99	2	100	12	...	12	...
Syntherisma filiformis	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Agropyron tenerum	0	0	0	0	0	0	0	0	0	0	0	20	0	...	0	...	0	99	0	...
Rumex crispus	0	98	0	...	0	...	0	99	0	99	0	99	0	99	0	99	0	...	0	...
Eragrostis major	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	10	...	10	...
Taraxacum officinale	0	3	0	3	0	3	0	50	0	80	0	90	2	97	2	100	14	...	16	...
Rumex persicarioides	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...	0	...
Verbena bracteosa	0	97	0	97	0	97	0	99	0	100	0	100	0	100	0	100	0	...	0	...

The factors which affect the number of weed seeds carried in irrigation ditches are as follows:

1. Flora of ditch bank and adjacent territory.
2. Season of the year.
3. Velocity and direction of wind.
4. Velocity of irrigation stream.
5. Buoyancy of weed seeds.

DITCH BANK VEGETATION

In the construction of irrigation ditches, both large and small, new soil is brought to the surface, and consequently the banks present a denuded surface (Fig. 2). This loose soil composing the banks is a favorable habitat in which weeds readily establish themselves. As a result, in a very few years, a new ditch, unless grazed, is densely overgrown with many species of weeds. The species of weeds represented on ditch banks are those inhabiting the roadsides and fields of the locality. On account of the water supply along ditches, the stand of weeds along them is denser and the individual plants are larger than along roadsides and in waste places. (Fig 3.)

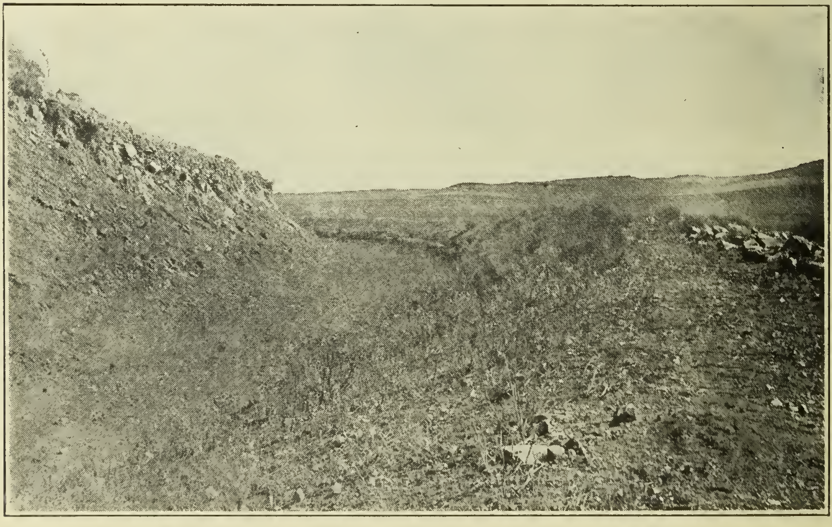

Fig. 2—A newly constructed ditch. The banks present a denuded surface, and a favorable situation in which weeds may establish themselves.

As a rule there is a greater number of weed species on a new ditch bank than on an old one. As vegetative development proceeds there is a reduction in the number of species and an increase in the number of individuals of the successful species.

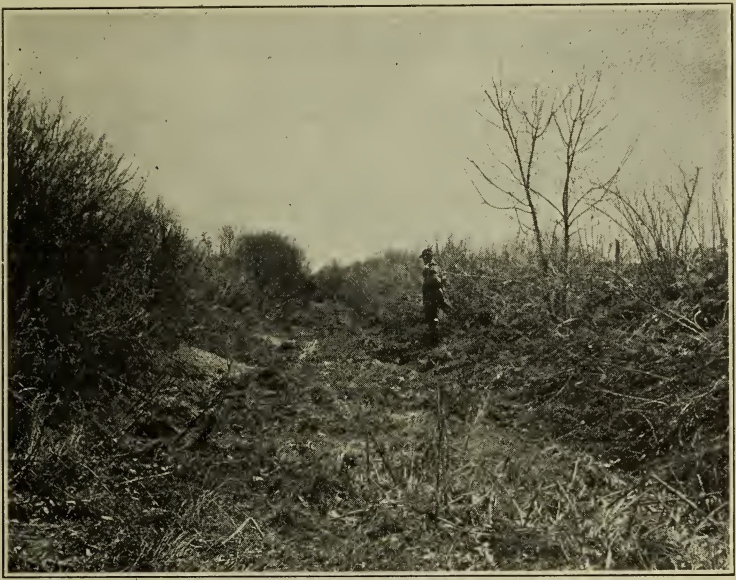

Fig. 3—An irrigation ditch heavily overgrown with tall weeds.

One may find on a section of an old ditch bank almost a pure stand of one or two weeds such as sweet clover *(Melilotus alba)*, tall ragweed *(Ambrosia trifida)*, Rocky Mountain beeplant *(Cleome serrulata)*, tall marsh elder *(Iva xanthifolia)*, and fire-ball *(Kochia scoparia)*. The above species often form rather pure stands along ditches. A few species of sedges, chiefly *Carex nebraskensis*, and the grasses, such as *Panicularia grandis*, become established at the water's edge along old ditches, and occupy the soil to the exclusion of other plants. These two species are not weeds in fields and their growth along ditch banks is to be encouraged. Furthermore, the grasses and sedges are excellent soil binders.

Ordinarily, there is little opportunity for a ditch bank to pass through a normal vegetative development. Almost annually there is disturbance of the habitat by the washing of water, by the cleaning of the ditch, and by the mowing of the vegetation. Consequently, in many respects, a ditch bank usually presents an early stage in plant succession, with its large number of species.

SEASONAL RELATIONS

When water is first turned into the ditches in the spring, there is an enormous number of weed seeds and debris of all kinds carried into the stream. During the irrigation season many weed seeds sink in transit and become lodged in the mud, and during the non-irrigation season there is a heavy accumulation of seeds in the soil of ditch bottoms and sides which are blown there by the wind. The first flush of water in the spring washes these seeds down with the current.

The greatest number of seeds comes with the first flush of water in the spring—reference is here made to samples collected in May and June. This being true, it would be advisable, when practicable, to avoid turning water into the field laterals and rows, until considerable water has been run through the ditches.

The seed-shedding period of some weeds is readily detected, of course, in the collections from the seed traps. This is particularly noticeable in the case of weeds which shed their seeds quite completely within a short period, such as the dandelion.

Following the first two or three weeks of flow in the spring there is a decrease in the amount of seeds and debris carried by the ditches. Reference is made to samples collected in July and August.

The weed seeds carried in irrigation streams are by no means only from weeds which border them. Seeds are carried long distances by the wind, fall in the water, and are conveyed by the current. The prevailing direction of the wind and the relative position of streams and weed infested areas, as well as the velocity of the stream, are factors which affect the number of seeds carried.

Seeds are carried long distances by streams. The distance any particular kind of seed will travel depends upon the velocity of the water, the character of the water surface, the specific gravity of the seed, and character of the seed coat. Some seeds, such as Indian mustard *(Brassica juncea)*, Hare's-ear mustard *(Conringia orientalis)*, Frenchweed *(Thlaspi arvense)*, broad-leaved plantain *(Plantago major)*, and Shepherd's purse *(Capsella bursa-pastoris)*, are heavier than water and sink immediately if agitated. Such seeds would not be carried long distances except in very swiftly running water.

If some seeds alight gently on the surface of water, and the water surface is undisturbed, as in the case of a slowly running stream, the seeds will float for a long time, but if the surface is agitated, as it would be in the case of a swiftly running stream, the seeds readily sink. See Table V.)

BUOYANCY OF WEED SEEDS

Some weed seeds float for an indefinite period if laid carefully upon a smooth water surface, and the surface is not disturbed (See Table IV). However, many of the same species of seeds sink if they fall on the surface from a short distance above the water. The following experiment in which seeds were dropped from a height of 5 feet upon a water surface was intended to simulate the situation along ditch banks where the seeds fall from weeds over-hanging the water.

TABLE VI.—BUOYANCY OF SEED—WHEN DROPPED INTO WATER FROM A HEIGHT OF 5 FEET THRU A ½" GLASS TUBE INTO A 250 C. C. BEAKER—100 SEEDS OF EACH SPECIES USED

Kind of Seed—	Floated	Sank
Echinochloa crus-galli	100	0
Rumex crispus (hulled)	33	67
Rumex crispus (unhulled)	100	0
Amaranthus graecizans	23	77
Sisymbrium altissimum	39	61
Solanum triflorum	50	50
Sophia incisa	76	24
Abutilon abutilon	28	72
Onagra strigosa	100	0
Portulaca oleracea	28	72
Hyocyamus niger	100	0
Cuscuta planiflora	52	48
Lolium temulentum	64	36
Capsella bursa-pastoris	70	30
Polygonum convolvulus	87	13
Carduus arvensis	96	4
Brassica arvensis	30	70
Plantago lanceolata	30	70
Thlaspi arvense	30	70

Kind of Seed—	Floated	Sank
Taraxacum officinale	100	0
Lactuca scariola	95	5
Gaura parviflora	95	5
Lappula occidentale	99	1
Amaranthus powelli	46	54
Brassica nigra	35	65
Datura stramonium	100	0
Brassica juncea	26	74
Salvia lanceolata	25	75
Cichorium intybus	78	22
Plantago major	48	52
Ambrosia artemisiifolia	100	0
Camelina sativa	65	35
Lepidium apetalum	82	18
Sonchus oleraceus	100	0
Eriogonum effusum	100	0
Heracleum lanatum	100	0
Aquilegia coerulea	20	80
Polanisia trachysperma	52	48
Tragopogon porrifolius	100	0
Syntherisma sanguinale	100	0
Ambrosia trifida	100	0
Amaranthus retroflexus	41	59
Panicum capillare	96	4
Conringia orientalis	17	83
Chenopodium album	36	64
Saponaria vaccaria	50	50
Helianthus petiolaris	79	21
Senecio spartioides	100	0
Polygonum persicaria	82	18
Syntherisma humifusum	100	0
Kochia scoparia	20	80
Euptoraium purpureum	100	0
Kuhnia glutinosa	100	0
Iva xanthifolia	100	0
Eragrostis major	2	98
Setaria viridis	46	54
Setaria glauca	94	6

GRAZING DITCH BANKS

One of the most effective and economical ways of keeping weeds down along irrigation ditches is by grazing. Sheep, cattle, and horses are used for this purpose. The fencing and grazing of the larger irrigation ditches is becoming a more common practice, and one to be strongly recommended. It is believed that in a few years measures will be taken to compel ditch companies to keep irrigation banks free from weeds. In some instances this may be accomplished by mowing (Fig. 4)

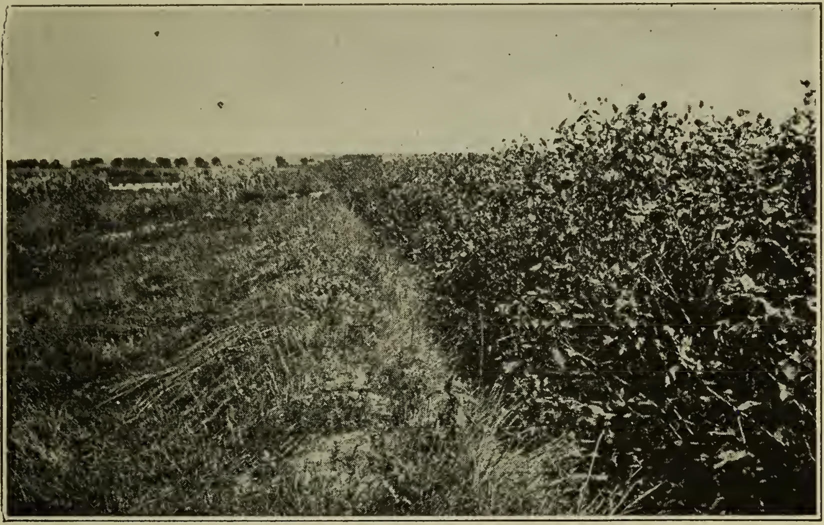

Fig. 4—A ditch between two farms. One farmer has mowed his side of the ditch, the other has allowed his to grow to weeds.

the weeds before seeding, but fencing and grazing will prove more effective, and the results more permanent. And, too, the area along ditches which is now worse than wasted, will not only be kept clean of weeds, but will be made to support several head of stock.

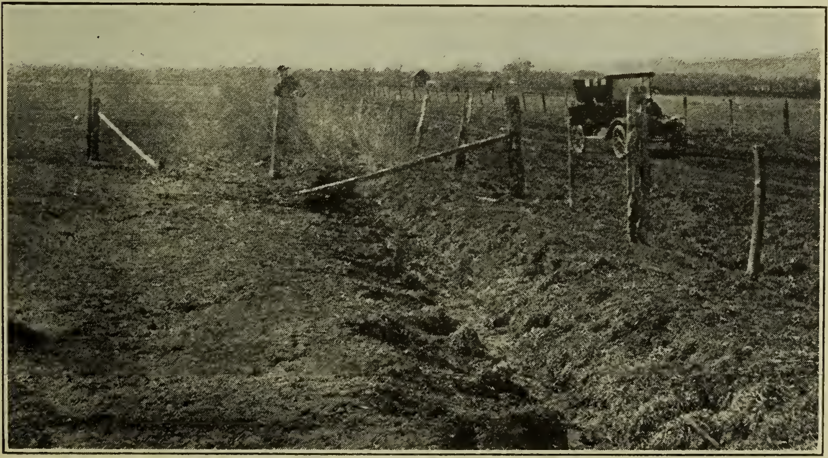

Fig. 5—In the foreground, the grazed ditch bank is free from weeds, while across the fence the ungrazed bank is overgrown with weeds.

The effects of grazing upon the vegetation of ditch banks are strikingly shown where one side or section of a ditch is grazed and the other side or adjacent section is ungrazed. Figure 5 graphically illustrates this.

It is not unusual to see grazed ditch banks grown over with a fair stand of grasses, chiefly Kentucky blue grass. Continued grazing results in rapid reduction of annuals, and a proportionate increase of perennials.

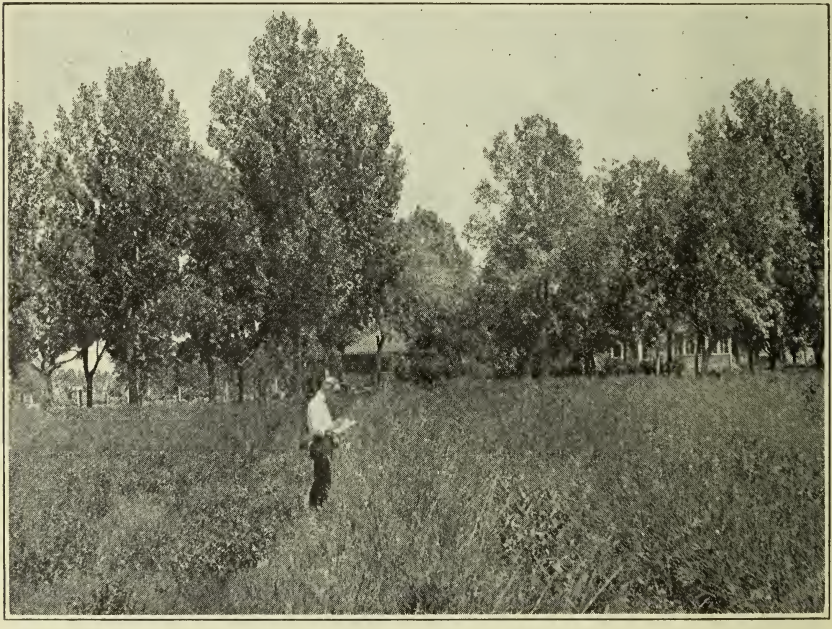

Fig. 6—Small lateral ditch bank densely overgrown with smooth brome grass. This grass occupies the ground to the almost total exclusion of weeds.

SEEDING OF DITCH BANKS

Figure 6 shows a small lateral ditch bank on the Agricultural College campus densely overgrown with smooth brome grass *(Bromus inermis)*. This perennial almost entirely excludes all weed growth. Its more general use on ditch banks should be encouraged. An excellent quality of seed is obtainable.

The writers acknowledge the assistance of Miss Caroline M. Preston, who made the drawing for Figure 1, and of Mr. George Spidel, who collected and analyzed many of the samples.

SUMMARY

1. Irrigation water is a most important factor in the dissemination of weed seeds in the irrigated sections of the western states, conveying tremendous quantities of weed seeds.

2. In 156 weed seed catches from three different ditches, a total of 81 different species of weeds were found, those most frequently met with being prostrate pigweed, tall pigweed, sedge, lamb's quarters, tall marsh elder, door weed, black bindweed, curled dock, and dandelion. The number of weed seeds passing a given point on a 12-foot ditch during a period of 24 hours may reach several millions.

3. Our ditch banks are more to be feared than roadsides as sources of weed infestation.

4. The early irrigation waters are most heavily loaded with weed seeds.

5. Many weed seeds rest during the non-irrigating season in the mud of the ditch.

6. Weed seeds differ in the readiness with which they sink or float and this is determined somewhat by the condition of the water surface and by the manner in which the seeds alight upon it.

7. Some seeds float for days no matter how they strike the water surface or how it is agitated; some float if laid on the water carefully and the surface is not disturbed, but sink readily if the surface is agitated, or sink almost immediately if they strike the surface with some force.

8. Ordinarily, grazing is one of the most effective and economical ways of keeping weeds down along large irrigation ditches.

9. In some instances, the seeding of ditch banks to bromegrass *(Bromus inermis)* is to be encouraged.

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Bulletin 254 January, 1920

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

ORCHARD SURVEY OF FREMONT COUNTY

BY

E. P. SANDSTEN and C. M. TOMPKINS

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

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ORCHARD SURVEY OF FREMONT COUNTY

By E. P. SANDSTEN AND C. M. TOMPKINS

The orchard survey of Fremont County was undertaken to ascertain the present status of the industry and to enable the department to render such aid as would benefit the fruit growers.

The value of a survey of this kind depends upon the accuracy of the information obtained and the completeness of the survey. On this account, it was decided to visit every orchard and obtain the information both by personal inspection and thru information obtained from the owner. With this accurate data, properly tabulated, the department has information which otherwise could not have been obtained—information that will be useful in the solution of some of the local problems confronting the grower.

It is the intention to make a similar survey in every fruit section of the State. To make the data of continuous value it should be kept up to date so that changes which may occur can be properly recorded. Conditions which obtained ten years ago do not obtain today, and conditions which exist today will not exist ten years hence.

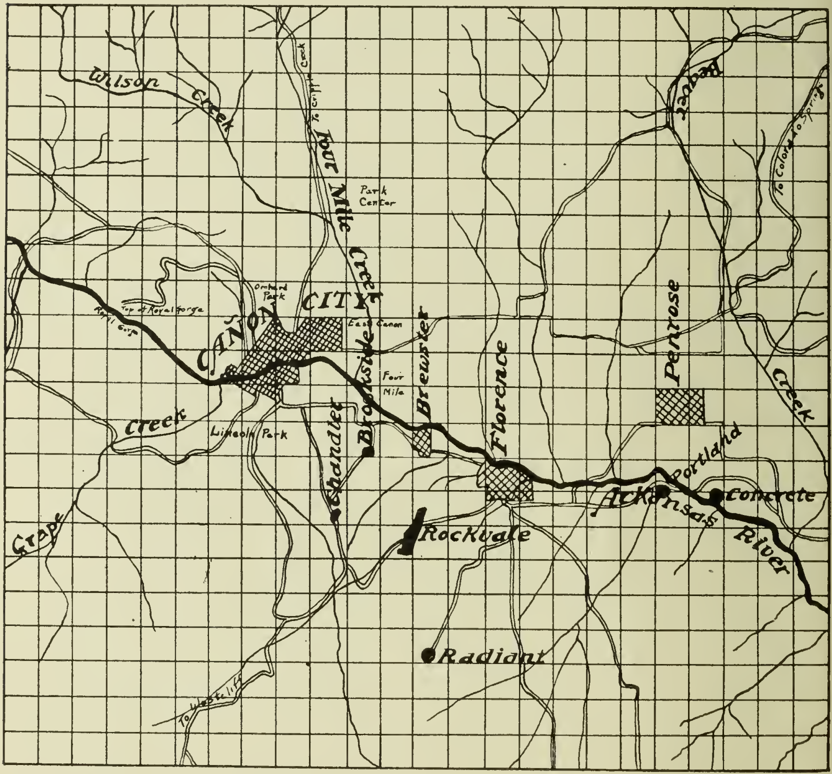
Fremont County, or, more properly, the Canon City fruit district, is the most important and most highly developed fruit district in Eastern Colorado. This development is due to the favorable location of the district; first, with reference to available water for irrigation; second, to the sheltered situation of the valley; third, to the soil conditions which are, on the whole, favorable or could be made favorable by drainage and by a better system of irrigation.

The valley is sheltered on three sides and open only to the south. The Arkansas River flows approximately thru the middle of the valley, which has sufficient fall to provide good soil and air drainage. The winter temperature and frost conditions are, on the whole, favorable, as will be seen by the accompanying meteorological data which is taken from the records of the United States Weather Bureau.

The fruit district is rather limited and confined to the valley proper and to the small, adjacent mesas. It lies in a compact body, well served by two systems of railroad. The only outlying district of importance is the Penrose or Beaver Creek district. This district is of recent development and is located on a secondary mesa on Beaver Creek, a tributary to the Arkansas River.

The Canon City district proper is the oldest developed fruit section on the Eastern Slope. The pioneer in fruit growing is Captain B. F. Rockafellow, who planted one of the first orchards in the valley, and to whom much credit should be given in the way of trying out varieties and experimenting, preparatory to the commercial development of later years.

One would naturally expect that in a district of this kind where the pioneer growers had no other guide than the nursery catalog, that numerous varieties would be planted which in later stages of development would prove unprofitable and worthless. The pioneer stage is long since passed, yet the numerous varieties, many of worthless commercial value, are still growing. There seems to exist in the district a reverence for these varieties because of, possibly, sentimental reasons, but their presence has exerted and is exerting a bad influence upon the fruit industry.


Wilson Creek
To Cripple Creek
Four Mile Creek
Park Center
Beaver
To Colorado Springs
Orchard Park
CANON CITY
East Canon
Top of Royal Gorge
Royal Gorge
Brookside
Four Mile
Brewster
Florence
Penrose
Creek
Grape Creek
Lincoln Park
Chandler
Portland
Concrete
Arkansas River
Rockvale
Radiant
To Westcliffe

Map Showing the Location of Orchard Areas in Fremont County

SOILS

Canon City District—The valley land proper is made up of soil deposited by the flood waters of the Arkansas River, and is consequently of alluvial character, the heavier types being further removed from the river bed, while the lighter or sandier types are relatively close to the river. The soil, being made by the action of water, is naturally rich in the essential elements of plant food, and produces unrivaled yields of farm crops. Many of the original trees, planted between 1865 and 1870, are still grow-g and producing crops, an eloquent testimony of soil fertility and the neral suitableness of the district for fruit growing. The higher lands, bench lands, which have come under cultivation during the last twenty-

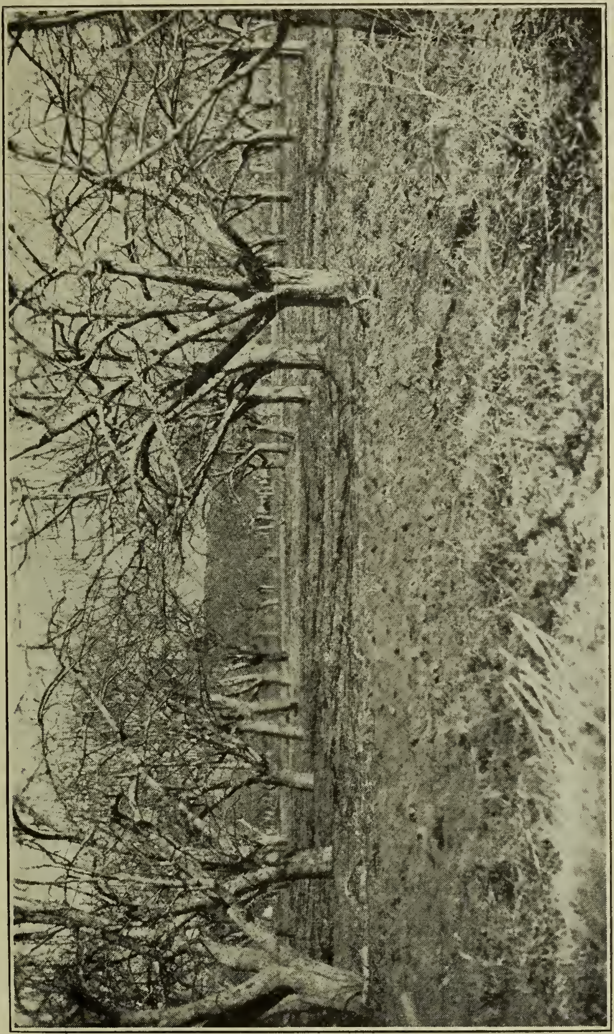


Fig. I. AN OLD APPLE ORCHARD IN EXCELLENT CONDITION.

e years, are, on the whole, better adapted to fruit growing than the land the valley.

The superiority of bench land is due, primarily, to better air and soil ainage. The soil of the bench land is derived from the adjacent hills d rock formations and is of medium heavy character. It is quite uniform, with a few exceptions where adobe is found, but this type of soil constitutes a very small percentage of the total land area. It is deep, with a porous subsoil, and there is no danger from seepage. It is easily worked and permits deep root penetration. On the whole, the soil around Canon City is admirably adapted for fruit growing and for the growing of truck crops.

The truck crops should be confined to the land close to the river, as it is of lighter character, on which the truck crops will mature earlier.

Florence District—The soil conditions around Florence are, in the main, similar to those around Canon City, tho there is a considerable acreage of very stiff, heavy soil. This is especially true on land located some distance from the river. On the whole, the section around Florence is more limited, more exposed and not so well adapted to fruit trees as around Canon City. Further, there is little or no bench land, or land at a much higher elevation than the valley proper. Truck growing in this section is of considerable importance and is growing rapidly. The land is owned in small parcels and worked entirely by members of the family. This makes the production of truck crops economical.

The Penrose or Beaver Creek District is of relatively late development. It lies about five miles due north of Florence. The land is a bench or mesa resting on a formation of magnesium, limestone, and sandstone with isolated areas of gypsum. The soil is of a fine, loose texture and generally deficient in vegetable matter. In many places the soil is too shallow for permanent tree growth, as the rock formation comes close to the surface. This makes permanent success in fruit growing questionable. Even on the deeper soils, the problem of seepage will sooner or later come up, since usually where the soil is deep there is a corresponding depression in the rock formation, and into this depression surplus water will collect, and unless there is an outlet for this water, it will accumulate and result in seeped areas. The lack of vegetable matter in the soil will make it necessary for the fruit growers to build it up, and this is a costly and tedious operation. The gypsum areas, while not large, are scattered over a considerable portion of the territory, and where these areas are of any great extent, fruit trees cannot be grown successfully.

The district, as a whole, is best adapted to the growing of sour cherries. Cherry trees are comparatively shallow-rooted, and on this account will thrive on the shallow land. They need, however, considerable attention in the matter of fertilization to make them productive. The soil requires a careful handling.

DRAINAGE

The orchards in the valley proper, especially on the north side of the river, are in need of drainage. Water for irrigation is both cheap and abundant, and this has led to the usual habit of irrigating whether moisture is needed or not. Too often it has led to the usual practice of substituting irrigation for cultivation. The lack of drainage is becoming more and more rious, and a considerable acreage of good fruit land is being ruined. The ocess of seepage is hastened by the drainage of the irrigation water from e higher land. Unless some action is taken, a considerable acreage now orchard will be lost. The facilities for drainage are excellent; the fal sufficient to carry the surplus water, and the soil is naturally of a mor less open texture. There is no hard-pan to obstruct the flow. The onl ason why seepage has not until recently become a menace, is due to th en texture of the soil and the slope of the land, but gradually the soil easily puddled, due to the lack of vegetable matter and the heavy, frequent rigation, and when kept in a puddled condition interferes with the natural ow of the underground water.

The drainage could easily and cheaply be solved by concerted action the land-owners. On the mesa the soil drainage, with one or two local ceptions, is excellent and seepage is not likely to cause any serious trouble.

Air Drainage—Few fruit districts in the State can boast a better air ainage than this district. The Arkansas River, as it breaks thru the non, flows swiftly thru the upper valley and creates a constant current air which prevents the colder air from settling in the form of frost. The pe of the land on both sides of the river is sufficient to carry the colder r towards the river current to be carried off by it. While destructive osts have happened in the valley, it should be said that so far as failure crops from belated spring frost is concerned, it is as safe as any known uit district.

ENERAL CONDITION OF ORCHARDS IN FREMONT COUNTY

No definite system of orchard management prevails, outside of a few mmercial orchards. Many of the older orchards are in permanent hay pasture crops, such as alfalfa, clover, and bluegrass. Where alfalfa d clovers are used, they are usually cut for hay. Orchards in bluegrass e often used for pastures. In most of the smaller orchards the spaces tween the tree rows are planted to small fruits and vegetables. Few chards are in clean cultivation. The general effect of these different ethods of culture is not satisfactory for the best fruit production, since none these practices provide the necessary soil fertility and proper soil contions. No matter how fertile the soil may originally have been, the ower cannot continue to take off one or more crops from the land each ar without sooner or later exhausting its fertility. The fact that the trees e not bearing a crop of fruit is no indication that they are not using a nsiderable amount of plant food for tree growth and for the development fruit buds. If, in addition to the food requirements of the trees, other ops are grown in the orchard, the drain on the soil becomes correspondgly severe.

There is a widespread belief that alfalfa planted in an orchard and rvested for hay increases the fertility of the soil. This belief is based upon the fact that alfalfa has proven beneficial as a crop in farm rotation, also from the fact that alfalfa, like other leguminous plants, appropriates the larger part of its nitrogen requirements from the air, thus adding this element of fertility to the soil. Granting that all this is true, we have the questions: How about the other necessary elements of plant food, such as phosphorous, potassium, and sulphur? How are these to be supplied? And are they not equally necessary in fruit production? For example, three tons of alfalfa permanently removes approximately 120 pounds of potash, and from 90 to 100 pounds of phosphorous per acre per year, and nothing of this amount is returned to the soil. In other words, the taking off of alfalfa from the land without returning an equal amount of plant food material in the shape of fertilizer, permanently impoverishes the soil to the extent of the amount removed. Permanent hay crops like alfalfa are not adapted to orchards, and alfalfa should not be kept for more than three years without being plowed under, and in doing this, the second or third crop should not be cut for hay.

The purpose of the cover crops in the orchard is not for the growing of feed for livestock, but for turning under so that the soil may be benefited, both in the matter of fertility and what is often equally important, in soil conditions.

With few exceptions, the orchards in the whole district show the effect of poor soil conditions or lack of soil fertility, or both. The lack of proper pruning is also apparent. The trees in the older orchards are practically stationary in their growth; the foliage is small and lacks the deep green color of healthy trees. The remedies for this general condition are to be found, first, in proper pruning; second, in the plowing up of the old sod in the fall or early spring, in clean cultivation during the early summer, and the seeding of the ground to a cover crop in the fall which is to be plowed under the following spring. (See Bulletin No. 250, "Orchard Management.")

The growing of small fruits and vegetables between bearing fruit trees is not profitable. The soil in a bearing orchard is generally too shaded for the crops to do well, and further, the bearing trees need all the fertility that the soil contains. While the trees are small, the land may be cropped, provided the fertility of the soil is maintained, and provided cultivation and irrigation do not injure the growth of the growing trees. Cultivated or hoed crops which mature early should be grown, since these permit the proper ripening of the trees in the fall before freezing weather sets in.

A considerable number of orchards are owned by non-residents and are cared for by renters. Out of a total of 687 orchards, 172 are owned by non-residents, and in addition, a large percentage is owned by residents of the county and cared for by renters or tenants. As a rule, fruit growing by proxy is unprofitable. The renter will naturally take all he can get, with the least possible expenditure of money and effort. This is especially true when the lease is for short duration. Under the tenant system, the chard soon begins to deteriorate and becomes unprofitable. The bringing ck or restoring of such orchards is always difficult, and in many cases, npossible. They often become centers of insect infestations and are a enace to the neighboring orchards. It would be far more profitable to e owners and better to the community if the fruit trees were entirely re-oved and the land utilized for other crops.

The fact that some of the growers have small holdings of from one five acres has made secondary cropping a common practice, and the ndition of the fruit-bearing trees show the bad effect of it. It is a well cognized fact that orchards of less than eight or ten acres cannot be ofitably operated, without additional land for the growing of other crops. his is due to high overhead charges, such as management and necessary uipment, for the cost is practically the same for the small orchard as for orchard of 30 or 40 acres.

These small land-owners would find it more profitable to cut out their ees and devote the land to small fruits and truck crops. This would ovide for more labor and eliminate losses due to failure of fruit crops and w prices. This suggestion is especially applicable where the soil and ost conditions are more or less unfavorable to fruit growing, or where e varieties grown are unprofitable or unsuited to the locality.

The land values are too high and the individual holdings too small make general farming profitable, and should not be attempted. The sec-on as a whole, except the Penrose district, is pre-eminently a horticultural ction, and for this reason alone, any changes should be in the direction growing a greater variety of horticultural crops.

While pointing out some of the bad conditions that exist in this sec-on, we should not overlook the brighter side of the industry. There are large number of wide-awake, up-to-date and successful fruit growers hose orchards are as well managed as any in the State, and who have monstrated the fact that fruit growing in this section is highly profitable.

The contrast between a well-managed orchard and a neglected one is apparent that visitors are apt to go away with the belief that the many oor orchards that now exist indicate a poor fruit district. A number of oorly-cared-for orchards have a depressing influence, not only on land lues, but also on the fruit industry as a whole.

CROPS GROWN IN THE ORCHARD

A study of the accompanying table shows that out of a total of 687 chards, only 150 are in clean cultivation; 270 orchards are in alfalfa d 181 planted to truck crops. The table does not show the fact that the falfa is universally cut for hay or cropped like an ordinary alfalfa field. he fruit trees, instead of being benefited by the alfalfa, are actually in-red, since the fertility removed is as great or greater than the fertility moved by a crop of fruit. The same is true of all other crops raised tween tree rows and removed from the land. Many orchards show the fect of this double cropping system.

CROPS GROWN IN THE ORCHARDS

	Alfalfa	Wheat	Clover	Oats	Berries	Truck	Clean	Rye	Peas	Barley
Lincoln Park—	14	4	13	7	44	63	74	1	1	..
East Canon—	144	8	9	4	9	52	37	..	..	2
Four Mile—	63	4	4	1	11	14	9	..	..	..
Penrose—	25	6	1	2	12	28	25	..	1	1
Florence—	7	1	..	..	2	12	2	..	..	1
Orchard Park—	9	..	1	..	1	5	1	..	..	..
Park Center—	8	8	3	..	2	7	3	..	..	..
	270	31	31	14	81	181	151	1	2	4

Counted twice, 251.

CLIMATOLOGICAL RECORDS OF THE CANON CITY DISTRICT

The following data were compiled from the records of the U. S. Weather Bureau. The figures show that the climatic conditions are, on the whole, very favorable for commercial fruit growing; the growing season is long enough to mature the better varieties of tree fruits. Few fruit-growing sections can show a more favorable record.

FROST DATA

Canon City, Fremont County (Elevation, 5,343 Feet)

Year	Date of last killing frost in spring	Date of first killing frost in autumn	Length of growing season—last killing frost to first killing frost (Days)	Latest date with temperature 32° or lower in the spring	Earliest date with temperature 32° or lower in autumn
1893	May 1	Oct. 1	153	May 7	Sept. 27
1894	May 23	Sept. 24	154	May 23	Sept. 24
1895	Apr. 22	Sept. 22	153	May 11	Sept. 22
1896	May 1	Oct. 10	162	May 1	Sept. 28
1897	Apr. 11	Oct. 17	189	Apr. 13	Oct. 12
1898	Apr. 13	Oct. 4	174	May 5	Oct. 4
1899	May 4	Oct. 18	167	May 5	Oct. 18
1900	Apr. 18	Sept. 28	163	Apr. 18	Sept. 23
1901	Apr. 18	Oct. 13	178	Apr. 20	Oct. 18
1902	Apr. 26	Oct. 25	182	Apr. 27	Sept. 12
1903	May 4	Sept. 17	136	May 12	Sept. 17
1904	Apr. 18	Oct. 19	184	May 14	Oct. 14
1905	Apr. 25	Oct. 1	159	May 12	Oct. 1
1906	Apr. 4	Oct. 21	200	Apr. 4	Oct. 24
1907	May 14	Nov. 11	181	May 15	Nov. 10
1908	May 6	Sept. 27	144	May 6	Sept. 26
1909	May 1	Oct. 9	161	May 1	Oct. 9
1910	May 22	Oct. 20	151	May 22	Oct. 4
1911	Apr. 16	Oct. 19	186	May 2	Oct. 19
1912	Apr. 22	Oct. 22	183	May 14	Sept. 25
1913	Apr. 25	Sept. 27	155	Apr. 25	Sept. 27
1914	Apr. 28	Nov. 8	194	Apr. 28	Oct. 5
1915	May 19	Oct. 7	141	May 20	Oct. 7
1916	May 15	Sept. 29	137	May 15	Sept. 29

Location of station in residence district of Canon City, about one mile north of river and like distance below mouth of Royal Gorge of Arkansas. Conditions at station typical of those that obtain in the cultivated region north of river, but probably more favorable to frost than those common to district south of river.

SUMMARY OF CLIMATOLOGICAL DATA

Precipitation

The mean annual precipitation from 1869 to 1916, inclusive, was 12.3 ches.

The annual snowfall for a period of 23 years was 36.4 inches.

Temperature

The mean temperature for a period of 29 years was 52.8°F.

The mean maximum temperature for a period of 24 years was 67.4°F.

The mean minimum temperature for a period of 24 years was 37.4°F.

The highest temperature for a period of 24 years was 104.0°F.

The lowest temperature for a period of 24 years was -30°F.

The prevailing wind for a period of 24 years was west.

Average Frost Date for a Period of Twenty-four Years

Average date of last killing frost in the spring, April 29.

Average date of first killing frost in the fall, October 10.

Latest date of killing frost in the spring, May 23.

Earliest date of killing frost in autumn, September 17.

XTENT OF FRUIT GROWING IN FREMONT COUNTY

The number of acres devoted to tree fruits in Fremont County is 688.16. This acreage represents practically all the land suitable for ee fruits. Further development of water supply for irrigation may bring additional small acreage of fruit land under cultivation, tho the availle area of suitable land is small and the cost of water for irrigation ould be high. Fruit growing is confined to a very limited area around anon City and at Penrose, tho the planting in this area is practically solid. he Penrose district shows a large number of trees, but many of these were anted on unfavorable sites and will never become of much commercial portance. This is particularly true of the apples. A glance at the table age of fruit trees shows a very high percentage of trees between the age 12 and 40, indicating that the early plantings are still surviving. The rcentage of trees below the age of 8 is relatively small, being less than 30 r cent. There have been practically no new plantings during the last ve years.

OWNERSHIP AND TENANCY

It is of interest to note that in classifying the 687 orchards in the unty, less than one-third are in good condition. The remaining twoirds are either in poor condition or neglected. Equally interesting is the cord of ownership, which shows that 150 orchards are owned by nonsidents and are cared for by tenants. Fruit growing by tenancy or by oxy is seldom profitable, since no definite system of management can be llowed, and further, tenants usually rent by the year and have only a mporary interest in the orchard.

In addition to these 150 non-resident owners, there are a relatively large number of orchards that are owned by resident owners who are not residing on the land. These owners usually have other business and the orchards are cared for either by a tenant or by a manager. This condition, while not as bad as the tenant system under non-resident owners, is, nevertheless, not conducive to the best results.

CANNERIES

With the establishment of canneries and preserving plants, the sour cherry industry has made a remarkable progress, and further development may be expected. The Penrose district is well adapted to cherry growing and will become an important sour cherry growing center. The soil around Penrose is better adapted to sour cherries than apples, and many of the apple orchards will be replaced with sour cherries. Sweet cherries are not grown to any extent and will probably never assume a commercial importance, as the climate is not adapted to this fruit.

NUMBER OF ORCHARDS IN FREMONT COUNTY

Lincoln Park	220
East Canon	127
Penrose	172
Four Mile	43
Florence	20
Park Center	24
Orchard Park	11
Inter-planted	70
Total	687
Resident growers	515
Non-resident growers	172
Total	687

NUMBER OF APPLE TREES IN EACH ORCHARD DISTRICT

Lincoln Park	43,485
East Canon	19,486
Four Mile	12,176
Penrose	77,370
Orchard Park	5,082
Florence	2,920
Park Center	5,383
Total trees	165,902

NUMBER OF APRICOT TREES IN EACH ORCHARD DISTRICT

Park Center	7
Four Mile	50
Total trees	57

NUMBER OF CHERRY TREES IN EACH ORCHARD DISTRICT

Lincoln Park	16,500
East Canon	2,512
Four Mile	2,695
Penrose	41,111
Orchard Park	852
Florence	680
Park Center	3,202
Total trees	67,552

NUMBER OF PEACH TREES IN EACH ORCHARD DISTRICT

Lincoln Park	80
Penrose	2
Orchard Park	6
Florence	10
Park Center	239
Total trees	337

NUMBER OF PEAR TREES IN EACH ORCHARD DISTRICT

Lincoln Park	588
East Canon	277
Four Mile	44
Penrose	71
Orchard Park	2
Park Center	5
Total trees	987

NUMBER OF PLUM TREES IN EACH ORCHARD DISTRICT

Lincoln Park	575
East Canon	458
Four Mile	135
Penrose	938
Orchard Park	383
Florence	49
Park Center	136
Total trees	2,674

VARIETIES OF APPLE TREES GROWN

The accompanying list of varieties of apples grown in Fremont County is surprisingly large, and indicates that the early planting was done without a definite knowledge of the commercial requirements, nor did they show what varieties would succeed. In all 90 varieties are recorded, with several unnamed kinds, bringing the total up to nearly 100. This large number is a positive drawback to the industry. The loss occasioned by worthless varieties is so great as to make many of the orchards unprofitable, and the fact that the average orchard is small (averaging 7⅔ acres) makes the presence of numerous varieties more undesirable, even were the varieties of commercial importance. In a limited district like this, six to eight commercial varieties are sufficient, and for individual orchards, two or three varieties are recommended.

The commercial grower should have a sufficient number of trees of each variety to enable him to ship in carload lots, unless there is a good local market. The cost of spraying, harvesting, and other orchard operations is more expensive where a large number of varieties is planted. Further, in shipping mixed carloads, the grower cannot obtain as high a price for his fruit as the shipper of straight carloads, or carloads containing a single variety.

A study of the table on page 15 shows that Jonathan is the leading commercial variety, with 51,145 trees, followed in order by Winesap, 36,192; Ben Davis, 33,378; Rome Beauty, 9,117; Gano, 8,391, and Delicious, 7,038. This proportion is very much like the proportion found in the other important fruit-growing sections of the State. Future commercial plantings will be made of these varieties, as experience shows that they are most profitable.

Many of these mixed orchards, where the trees are healthy, could be made more profitable by top grafting. A few growers are doing this, but the majority are still retaining the worthless kinds. The orchards are, as a rule, strictly commercial, containing the best varieties, and are managed so as to bring the maximum returns.

NUMBER OF TREES OF EACH VARIETY OF APPLES GROWN IN FREMONT COUNTY

1.	Ben Davis	33,378
2.	Colorado Orange	1,045
3.	Delicious	7,038
4.	Gano	8,391
5.	Geniton	2,955
6.	Jonathan	51,145
7.	Paragon	1,028
8.	Rambo	971
9.	Rome Beauty	9,117
10.	Wealthy	1,595
11.	Winesap	36,192
12.	Yellow Transparent	2,784
13.	Missouri Pippin	2,086
14.	White Winter Pearmain	306
15.	Vandeveer Pippin	4
16.	Maiden Blush	340
17.	Early Harvest	239
18.	Walbridge	619
19.	Red Astrachan	159
20.	Chenango Strawberry	67
21.	Duchess	377
22.	Red June	437
23.	Northern Spy	165
24.	Haas	115
25.	Cedar Hill Black	40
26.	York Imperial	943
27.	Stayman Winesap	499
28.	Arkansas Black	180
29.	Baldwin	100
30.	Belleflower	130
31.	Champion	166
32.	Fall Pippin	29
33.	Flora Bell	24
34.	Gravenstein	6
35.	Grimes Golden	335
36.	Huntsman's Favorite	164
37.	Jefferis	172
38.	King David	199
39.	Lawver	18
40.	McIntosh Red	189
41.	Minkler	34
42.	Newtown Pippin	77
43.	Northwestern Greening	61
44.	Shackleford	92
45.	Willow Twig	87
46.	Wolf River	34
47.	Snow	160
48.	Wagner	128
49.	Fulton	5
50.	Sop	2
51.	Smokehouse	5
52.	Buckingham	2
53.	Sheriff	145
54.	McMahon's White	6
55.	Shield's Crab	2
56.	Sheepnose	31
57.	Whitney Crab	2
58.	Iowa Blush	10
59.	Virginia Sweet	6
60.	Tolman Sweet	99
61.	Commerce	27
62.	Pomade	8
63.	Roman Stem	2
64.	Missing Link	22
65.	Cooper White	15
66.	Limbertwig	2
67.	Romanite	14
68.	La France	2
69.	Winter Banana	22
70.	Fall Queen	124
71.	Opalescent	10
72.	Senator	86
73.	Culver	4
74.	Summer Queen	5
75.	Golden Pippin	1
76.	Tetofsky	3
77.	Lowell	133
78.	Ben Hur	5
79.	Rawles' Janet	10
80.	Liveland Raspberry	3
81.	Rhode Island Greening	4
82.	Early Ripe	3
83.	Mann	8
84.	Porter	93
85.	Twenty-Ounce Pippin	93
86.	Red Winter Pearmain	93
87.	Bailey Sweet	93
88.	Canon White	93
89.	Sweet Pear	93
90.	Striped Gilliflower	93
	Unknown	3

NUMBERS AND VARIETIES OF APPLE TREES GROWN IN FREMONT COUNTY, AND THEIR DISTRIBUTION

	Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Flor-ence	Park Center
1.	Ben Davis	16,730	4,622	1,895	7,967	622	749	793
2.	Colorado Orange	606	142	122	.....	88	77	10
3.	Delicious	307	58	201	6,273	50	80	69
4.	Gano	4,771	619	173	1,598	580	137	513
5.	Geniton	1,299	727	436	172	297	14	10
6.	Jonathan	7,559	4,376	2,802	32,764	940	953	1,757
7.	Paragon	352	336	123	18	40	.....	159
8.	Rambo	270	378	125	.....	114	31	53
9.	Rome Beauty	1,396	930	163	5,984	318	43	283
10.	Wealthy	555	442	208	13	205	72	100
11.	Winesap	5,574	3,711	2,298	21,688	1,570	332	1,019
12.	Yellow Transparent	1,064	1,018	284	85	125	106	102
13.	Missouri Pippin	834	672	291	108	8	53	120
14.	White Winter Pearmain	26	146	107	4	4	.....	19
15.	Vandeveer Pippin	.....	.....	.....	.....	2	.....	2
16.	Maiden Blush	112	40	168	3	2	5	10
17.	Early Harvest	34	37	152	3	14	.....	.....
18.	Walbridge	140	301	113	16	2	42	5
19.	Red Astrachan	2	14	137	.....	6	.....	.....
20.	Chenango Strawberry	10	6	.....	25	8	15	3
21.	Duchess	90	107	147	.....	17	11	5
22.	Red June	88	232	110	3	2	2	.....
23.	Northern Spy	18	33	94	15	3	.....	2
24.	Haas	13	7	93	.....	2	.....	.....
25.	Cedar Hill Black	.....	.....	.....	.....	40	.....	.....
26.	York Imperial	682	62	111	10	1	40	37
27.	Stayman Winesap	90	32	.....	228	20	60	69
28.	Arkansas Black	69	62	19	16	2	.....	12
29.	Baldwin	1	6	93	.....	.....	.....	.....
30.	Belleflower	23	.....	95	10	.....	.....	2
31.	Champion	55	25	.....	34	.....	.....	52
32.	Fall Pippin	29	.....	.....	.....	.....	.....	.....
33.	Flora Bell	20	1	.....	.....	.....	3	.....
34.	Gravenstein	6	.....	.....	.....	.....	.....	.....
35.	Grimes Golden	83	6	105	112	.....	.....	29
36.	Huntsman's Favorite	46	7	111	.....	.....	.....	.....
37.	Jefferis	54	56	62	.....	.....	.....	.....
38.	King David	11	.....	25	83	.....	77	3
39.	Lawver	6	1	2	.....	.....	9	.....
40.	McIntosh Red	86	.....	103	.....	.....	.....	.....
41.	Minkler	2	.....	32	.....	.....	.....	.....
42.	Newtown Pippin	17	.....	.....	60	.....	.....	.....
43.	Northwestern Greening	2	59	.....	.....	.....	.....	.....
44.	Shackleford	77	15	.....	.....	.....	.....	.....
45.	Willow Twig	10	7	.....	40	.....	.....	30
46.	Wolf River	19	9	6	.....	.....	.....	.....
47.	Snow	47	18	95	.....	.....	.....	.....
48.	Wagner	30	5	.....	.....	.....	.....	.....
49.	Fulton	5	.....	.....	.....	.....	.....	.....
50.	Sop	2	.....	.....	.....	.....	.....	.....
51.	Smokehouse	5	.....	.....	.....	.....	.....	.....
52.	Buckingham	2	.....	.....	.....	.....	.....	.....
53.	Sheriff	40	.....	105	.....	.....	.....	.....
54.	McMahon's White	6	.....	.....	.....	.....	.....	.....
55.	Shield's Crab	2	.....	.....	.....	.....	.....	.....

NUMBERS AND VARIETIES OF APPLE TREES GROWN IN FREMONT COUNTY, AND THEIR DISTRIBUTION

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Flor-ence	Park Center
56. Sheepnose	19	5	7	.....	.....	.....	.....
57. Whitney Crab	2	.....	.....	.....	.....	.....	.....
58. Iowa Blush	1	3	.....	.....	.....	.....	6
59. Virginia Sweet	6	.....	.....	.....	.....	.....	.....
60. Tolman Sweet	6	.....	93	.....	.....	.....	.....
61. Commerce	27	.....	.....	.....	.....	.....	.....
62. Pomade	8	.....	.....	.....	.....	.....	.....
63. Roman Stem	2	.....	.....	.....	.....	.....	.....
64. Missing Link	10	12	.....	.....	.....	.....	.....
65. Cooper White	12	3	.....	.....	.....	.....	.....
66. Limbertwig	2	.....	.....	.....	.....	.....	.....
67. Romanite	10	.....	4	.....	.....	.....	.....
68. La France	.....	.....	.....	.....	.....	2	.....
69. Winter Banana	.....	.....	.....	10	.....	7	5
70. Fall Queen	.....	92	18	.....	.....	.....	14
71. Opalescent	.....	.....	.....	.....	.....	.....	10
72. Senator	.....	.....	.....	6	.....	.....	80
73. Culver	.....	4	.....	.....	.....	.....	.....
74. Summer Queen	.....	5	.....	.....	.....	.....	.....
75. Golden Pippin	.....	1	.....	.....	.....	.....	.....
76. Tetofsky	.....	3	.....	.....	.....	.....	.....
77. Lowell	.....	40	93	.....	.....	.....	.....
78. Ben Hur	.....	.....	.....	5	.....	.....	.....
79. Rawles' Janet	.....	.....	.....	10	.....	.....	.....
80. Liveland Raspberry.	.....	.....	.....	3	.....	.....	.....
81. Rhode Island Greening	.....	.....	.....	4	.....	.....	.....
82. Early Ripe	.....	.....	3	.....	.....	.....	.....
83. Mann	.....	.....	8	.....	.....	.....	.....
84. Porter	.....	.....	93	.....	.....	.....	.....
85. Twenty-Ounce Pippin	.....	.....	93	.....	.....	.....	.....
86. Red Winter Pearmain	.....	.....	93	.....	.....	.....	.....
87. Bailey Sweet	.....	.....	93	.....	.....	.....	.....
88. Canon White	.....	.....	93	.....	.....	.....	.....
89. Sweet Pear	.....	.....	93	.....	.....	.....	.....
90. Striped Gilliflower...	.....	.....	93	.....	.....	.....	.....
Unknown	.....	.....	3	.....	.....	.....	.....
	43,485	19,486	12,176	77,370	5,082	2,920	5,383

Distribution, Acreage, Trees, Age, and Condition

	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
No. Acres	998.25	459.0	326.5	1,613.5	121.5	59.0	128.25
No. Trees	42,719	19,502	15,288	77,420	5,182	2,918	5,546
Age 8	1,470	545	1,930	12,490	300	30	216
Age 8-12	7,053	3,343	1,930	53,490	1,220	1,040	810
Age 12-40	34,196	15,614	11,428	1,440	3,662	1,848	4,520
Fair Condition....	71	52	16	35	4	13	10
Good Condition...	93	26	15	3	5	5	10
Poor Condition...	56	49	12	32	2	1	4

Summary

No. Acres	3,706.0
No. Trees	168,575
Age 8	16,981
Age 8-12	68,886
Age 12-40	82,708

Condition of Orchards

Fair	201
Good	157
Poor	156

CHERRIES

The growing of sour cherries is becoming an important industry. The cherry is a regular bearer, hardy and well adapted to the soil and climatic conditions of the county. With the establishment of canneries, there is a steady demand for the fruit at attractive prices.

The limited available acreage around Canon City will prevent extensive planting of this fruit, but the Penrose district will undoubtedly in the near future develop into an important sour cherry-growing section.

NUMBER AND VARIETIES OF CHERRY TREES IN FREMONT COUNTY

1.	Early Richmond	13,493	6.	Ostheim	294
2.	English Morello	8,593	7.	Mercer	19
3.	Montmorency	32,231	8.	Governor Wood	19
4.	Wragg	12,455	9.	Royal Duke	100
5.	Dyehouse	148	10.	Unknown	190
	Total				67,542

VARIETIES OF CHERRIES AND THEIR DISTRIBUTION

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
Early Richmond	4,964	896	659	5,422	397	296	859
English Morello	3,962	519	632	2,240	245	131	864
Montmorency	6,232	914	1,196	22,188	210	216	1,275
Wragg	1,153	178	179	10,760	.....	13	172
Dyehouse	95	.....	8	25	.....	.....	20
Ostheim	32	.....	6	225	.....	21	10
Mercer	.....	.....	.....	19	.....	.....	.....
Governor Wood	.....	.....	.....	19	.....	.....	.....
Royal Duke	.....	.....	.....	100	.....	.....	.....
Unknown	62	5	15	113	.....	3	2
Totals	16,500	2,512	2,695	41,111	852	680	3,202

Distribution, Acreage, Trees, Age, and Condition

	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
No. Acres	330.02	50.04	53.9	1,349.98	17.04	13.58	67.04
No. Trees	16,501	2,502	2,695	67,499	852	679	3,352
Age 8	4,749	719	345	52,677	100	125	1,235
Age 8-12	6,977	1,427	1,935	14,822	197	379	1,155
Age 12-40	4,785	356	415	.....	555	175	962
Fair condition	96	41	14	30	4	10	12
Good Condition	68	13	11	4	3	5	9
Poor Condition	57	32	8	32	2	.....	3

Summary

No. Acres	1,881.60
No. Trees	94,080
Age 8	59,940
Age 8-12	26,892
Age 12-40	7,248

Condition of Orchards

Fair	207
Good	113
Poor	134

Plums were formerly grown to a large extent, but the trees are short-lived and the older plantings are dying out and few replacements are being made. Practically all varieties of plums can be grown successfully.

NUMBER AND VARIETIES OF PLUM TREES IN FREMONT COUNTY

1.	Damson	375
2.	German Prune	212
3.	Green Gage	202
4.	Lombard	778
5.	Wild Goose	941
6.	Peach	5
7.	Italian Prune	14
8.	Bradshaw	16
9.	Shropshire Damson	25
10.	Pond's Seedling	31
11.	Yellow Egg	16
12.	Pottawattamie	9
13.	Weaver	5
14.	DeSoto	9
15.	Abundance	3
16.	Chickasaw	8
17.	Wolf	12
18.	French	2
19.	Omaha	4
20.	Garden City	5
21.	Unknown	2
	Total	2.674

NUMBER AND VARIETIES OF PLUMS IN FREMONT COUNTY AND THEIR DISTRIBUTION

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center	Totals
1. Damson	55	55	76	53	113	13	10	375
2. German Prune	14	6	20	168	.....	4	.....	212
3. Green Gage	53	.....	.....	136	.....	.....	13	202
4. Lombard	114	11	22	450	125	13	43	778
5. Wild Goose	229	383	9	111	140	19	50	941
6. Peach	.....	.....	.....	.....	5	.....	.....	5
7. Italian Prune	3	.....	.....	6	.....	.....	5	14
8. Bradshaw	16	.....	.....	.....	.....	.....	.....	16
9. Shrop. Damson	15	.....	.....	10	.....	.....	.....	25
10. Pond's Seedl'g	25	3	3	.....	.....	.....	.....	31
11. Yellow Egg	16	.....	.....	.....	.....	.....	.....	16
12. Pottawattamie	9	.....	.....	.....	.....	.....	.....	9
13. Weaver	5	.....	.....	.....	.....	.....	.....	5
14. DeSoto	8	.....	.....	.....	.....	.....	1	9
15. Abundance	3	.....	.....	.....	.....	.....	.....	3
16. Unknown	2	.....	.....	.....	.....	.....	.....	2
17. Chickasaw	8	.....	.....	.....	.....	.....	.....	8
18. Wolf	.....	.....	.....	.....	.....	.....	12	12
19. French Prune	.....	.....	.....	.....	.....	.....	2	2
20. Omaha	.....	.....	.....	4	.....	.....	.....	4
21. Garden City	.....	.....	5	.....	.....	.....	.....	5
Totals	575	458	135	938	383	49	136	2,674

Distribution, Acreage, Trees, Age, and Condition

	Park Lincoln	Canon East	Mile Four	Penrose	Orchard Park	Florence	Park Center
No. Acres	11.66	9.16	2.24	18.76	7.66	1.18	2.72
No. Trees	583	458	132	938	383	59	136
Age 8	61	126	83	248	.....	.....	25
Age 8-12	331	171	28	690	62	.....	57
Age 12-40	191	161	21	.....	321	59	54
Fair Condition	24	16	2	7	3	2	4
Good Condition	23	5	3	3	3	2	4
Poor Condition	13	5	1	9	.....	.....	1

Summary

No. Acres	53.38
No. Trees	2,689
Age 8	543
Age 8-12	1,339
Age 12-40	807

Condition of Orchards

Fair	58
Good	43
Poor	29

Pears are successfully grown around Canon City, but the industry is not of much commercial importance. Pear blight has been very destructive, and only some of the older plantings remain. No new plantings have been made during the last few years.

NUMBER AND VARIETIES OF PEARS IN FREMONT COUNTY

1.	Anjou	54
2.	Bartlett	673
3.	Flemish Beauty	42
4.	Keiffer	59
5.	Seckel	45
6.	Duchess	62
7.	Winter Nelis	11
8.	Hilo	1
9.	White Goyene	5
10.	Louis Bonne of Jersey	11
11.	Unknown	25

Distribution

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center	Totals
Anjou	43	2	.....	4	.....	.....	5	54
Bartlett	354	263	5	51	.....	.....	.....	673
Flemish Beauty	30	12	.....	.....	.....	.....	.....	42
Keiffer	56	.....	.....	1	2	.....	.....	59
Sugar (Seckel)	19	.....	12	14	.....	.....	.....	45
Duchess	62	.....	.....	.....	.....	.....	.....	62
Winter Nelis	11	.....	.....	.....	.....	.....	.....	11
White Goyene	.....	.....	5	.....	.....	.....	.....	5
Louis Bonne of Jersey	.....	.....	10	.....	.....	.....	.....	10
Unknown	13	.....	12	1	.....	.....	.....	26
Grand Total								987

Distribution, Acreage, Trees, Age, and Condition

	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
No. Acres	11.84	5.54	1.00	1.42	.....	.....	.....
No. Trees	592	277	44	71	2	.....	5
Age 8	114	127	12	43	2	.....	.....
Age 8-12	166	84	3	28	.....	.....	.....
Age 12-40	312	66	29	.....	.....	.....	5
Fair Condition....	30	7	3	3	1	.....	.....
Good Condition...	24	2	1	1	.....	.....	1
Poor Condition...	14	4	.....	2	.....	.....	.....

Summary

No. Acres	19.80
No. Trees	991
Age 8	298
Age 8-12	286
Age 12-40	407

Condition of Orchards

Fair	44
Good	29
Poor	20

Peaches were formerly of considerable importance, but of late years the trees have been reduced to almost nothing. Climatic conditions are responsible for this condition. The same is true in regard to apricots. Only in a few favored localities or situations can they be grown.

NUMBER AND VARIETIES OF PEACH TREES IN FREMONT COUNTY

1.	Elberta	282
2.	Yellow Freestone	36
3.	Early Crawford..	3
4.	Mountain Rose	15
5.	Un-named	1
	Total	337

Distribution

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Flor-ence	Park Center	Totals
Elberta	41	.....	.....	1	6	10	224	282
Yellow Freestone	36	.....	.....	.....	.....	.....	.....	36
Early Crawford..	3	.....	.....	.....	.....	.....	.....	3
Mountain Rose...	.....	.....	.....	.....	.....	.....	15	15
Japan Seedling..	.....	.....	.....	1	.....	.....	.....	1
								Grand Total
Totals	80			2	6	10	239	337

PEACHES

Distribution, Acreage, Trees, Age, and Condition

	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
No. Acres	1.6	.....	.....	.....	.....	.....	4.78
No. Trees	80	.....	.....	2	6	10	239
Age 8	2	.....	.....	2	.....	.....	.....
Age 8-12	31	.....	.....	.....	.....	.....	.....
Age 12-40	47	.....	.....	.....	6	10	239
Fair Condition	6	.....	.....	1	.....	.....	2
Good Condition	1	.....	.....	.....	.....	1	2
Poor Condition	3	.....	.....	.....	1	.....	.....

Summary

No. Acres	6.38
No. Trees	337
Age 8	4
Age 8-12	31
Age 12-40	302

Condition of Orchards

Fair	9
Good	4
Poor	4

VARIETIES OF APRICOTS AND THEIR DISTRIBUTION

Variety	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
Moorpark	.....	.....	.....	.....	.....	.....	7
Early Orange	.....	.....	50	.....	.....	.....	.....

Distribution, Acreage, Trees, Age, and Condition

	Lincoln Park	East Canon	Four Mile	Penrose	Orchard Park	Florence	Park Center
No. Acres	.....	.....	1	.....	.....	.....	.....
No. Trees	2	.....	50	.....	.....	.....	5
Age 8	.....	.....	20	.....	.....	.....	.....
Age 8-12	2	.....	20	.....	.....	.....	.....
Age 12-40	.....	.....	10	.....	.....	.....	5

TABLE I. NUMBER OF FRUIT TREES IN EACH DISTRICT

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	District Totals
Lincoln Park	42,719	592	80	583	2	16,501	60,477
East Canon	19,502	277	.....	458	.....	2,502	22,739
Four Mile	15,288	44	.....	132	50	2,695	18,209
Orchard Park	5,182	2	6	383	.....	852	6,425
Park Center	5,546	5	239	136	5	3,352	9,283
Florence	2,918	.....	10	59	.....	679	3,666
Penrose	77,420	71	2	938	.....	67,499	145,930
Valley Totals	168,575	991	337	2,689	57	94,080	266,729

TABLE I-a. DISTRIBUTION (in Percentages) OF TOTAL NUMBER OF TREES OF EACH FRUIT IN FREMONT COUNTY BY DISTRICTS

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	Entire Valley
Lincoln Park	25.5	60.2	23.6	21.6	3.5	17.6	22.7
East Canon	11.6	27.4	.....	17.1	.....	2.6	8.5
Four Mile	9.0	4.5	.....	4.8	87.7	2.8	6.8
Orchard Park	3.0	0.2	1.8	14.1	.....	0.9	2.4
Park Center	3.2	0.5	71.0	5.2	8.8	3.5	3.4
Florence	1.8	.....	2.9	2.3	.....	0.8	1.3
Penrose	45.9	7.2	0.7	34.9	.....	71.8	54.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE I-b. SHOWING RATIO (In Percentage) EACH FRUIT BEARS TO TOTAL NUMBER OF ALL FRUIT TREES FOR EACH DISTRICT

District	Apples	Pears	Peaches	Plums	Apricots	Cherries	Total
Lincoln Park	70.6	0.9	0.1	0.9	.....	27.5	100.0
East Canon	85.8	1.3	.....	2.0	.....	10.9	100.0
Four Mile	83.9	0.2	.....	0.8	0.2	14.9	100.0
Orchard Park	80.7	.....	.....	5.9	.....	13.4	100.0
Park Center	59.7	.....	2.5	1.5	.....	36.3	100.0
Florence	79.4	.....	0.3	1.6	.....	18.7	100.0
Penrose	53.0	.....	.....	0.6	.....	46.4	100.0
Entire Valley	31.6	0.2	0.1	0.5	17.6	50.0	100.0

TABLE II. NUMBER OF ACRES OF ORCHARD FOR EACH DISTRICT IN FREMONT COUNTY

	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	County Totals
Apples	998.25	459.00	326.50	121.50	128.25	59.00	1,613.50	3,706.00
Apricots	......	......	1.00	......	......	......	....	1.00
Cherries	330.02	50.04	53.90	17.04	67.04	13.58	1,349.98	1,881.60
Peaches	1.60	......	......	......	4.78	......	....	6.38
Pears	11.84	5.54	1.00	......	......	......	1.42	19.80
Plums	11.66	9.16	2.24	7.66	2.72	1.18	18.76	53.38
Totals, all Fruits..	1,353.37	523.74	384.64	146.20	202.79	73.76	2,983.66	5,668.16

TABLE II-a. NUMBER OF ACRES ORCHARD OF BEARING AGE FOR EACH DISTRICT

	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	County Totals
Apples	824.98	379.14	267.16	97.64	106.60	57.76	1,098.60	2,831.88
Apricots	0.04	......	0.80	......	......	......	....	0.84
Cherries	235.24	35.66	47.00	15.04	42.34	11.08	296.40	682.76
Peaches	1.56	......	......	0.12	4.78	0.20	....	6.66
Pears	9.56	3.00	0.64	......	0.10	......	0.56	13.86
Plums	10.24	6.64	0.98	7.66	2.22	1.18	13.80	42.72
Totals, all Fruits..	1,081.62	424.44	316.58	120.46	156.04	70.22	1,409.36	3,578.72

TABLE III. SIX PRINCIPAL VARIETIES OF APPLES, SHOWING PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE COUNTY

Variety	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
Jonathan	17.7	22.4	18.3	18.1	31.7	32.6	42.3	30.3
Winesap	13.0	19.0	15.0	30.3	18.3	11.4	28.0	21.4
Ben Davis.....	39.1	23.7	12.3	12.0	14.3	25.6	10.2	19.8
Rome Beauty..	3.2	4.7	1.1	6.1	5.1	1.4	7.7	5.4
Gano	11.1	3.1	1.1	11.2	9.2	4.7	2.1	4.9
Delicious	0.7	.2	1.3	.9	1.2	2.7	8.1	4.1
All others (over 85 varieties)	15.2	26.9	50.9	21.4	20.2	21.6	1.6	14.1
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE IV. THREE PRINCIPAL VARIETIES OF PEARS, SHOWING PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE COUNTY

Variety	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
Bartlett	59.8	94.9	11.4	......	......	......	71.8	67.9
Keiffer	9.4	......	......	100.0	......	......	1.4	5.9
Anjou	7.2	.8	......	......	100.0	......	5.6	5.4
All others (over 9 varieties).	23.6	4.3	88.6	......	......	......	21.2	20.8
Totals	100.0	100.0	100.0	100.0	100.0		100.0	100.0

TABLE V. PRINCIPAL VARIETIES OF PLUMS AND PRUNES, SHOWING PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE COUNTY

Variety	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
Wild Goose ...	39.8	83.6	6.6	36.5	36.8	38.8	11.8	34.9
Lombard	19.8	2.4	16.3	32.6	31.6	26.5	47.9	28.9
Blue Damson..	9.5	12.0	56.3	29.0	7.3	26.6	5.6	13.9
German Prune	2.4	1.3	14.8	......	......	8.2	16.8	7.8
Green Gage....	9.2	......	......	......	9.5	......	14.5	7.4
Pond's Seedling	4.3	.7	2.2	......	......	......	......	1.1
All others (over 15 varieties)	15.0	......	3.8	1.9	13.8	......	3.4	6.0
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE VI. PRINCIPAL VARIETIES OF CHERRIES, SHOWING PERCENTAGE GROWN IN EACH DISTRICT AND IN ENTIRE COUNTY

Variety	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
Montmorency..	37.7	36.3	44.3	24.6	39.8	31.7	53.9	34.2
Early Richm'd	30.0	35.6	24.4	46.5	26.8	43.5	13.1	14.3
Wragg	6.9	7.0	6.6	......	5.3	1.9	26.1	13.2
Eng. Morello..	24.0	20.6	23.4	28.9	26.9	19.2	5.4	9.1
Ostheimer	.1	......	.2	......	.3	3.0	.5	.3
Dyehouse	.5	......	.3	......	.6	......	.1	.2
Royal Duke...	.....	......	......	......	......	......	.2	.1
All others (8 varieties) ...	.8	.5	.8	......	.3	.7	.7	28.6
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE VII. NUMBER OF APPLE TREES OF EACH DISTRICT AND OF ENTIRE COUNTY BY AGE CLASS

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Totals
1-8 years	1,470	545	1,930	300	216	30	12,490	16,981
8-12 years	7,053	3,343	1,930	1,220	810	1,040	53,490	68,886
12-40 years ...	34,196	15,614	11,428	3,662	4,520	1,848	1,440	82,708
Totals	42,719	19,502	15,288	5,182	5,546	2,918	67,820	168,575

TABLE VII-a. PERCENTAGE OF APPLE TREES OF EACH AGE PLANTED IN EACH DISTRICT

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Totals
1-8 years	8.6	3.2	11.3	1.7	1.2	0.2	73.8	100.0
8-12 years	10.2	4.8	2.8	1.7	1.1	1.5	77.9	100.0
12-40 years ...	47.0	21.4	15.7	5.0	6.2	2.5	2.2	100.0

TABLE VII-b. PERCENTAGE OF APPLE TREES OF EACH DISTRICT WITH RESPECT TO AGE

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Totals
1-8 years	3.4	2.8	12.6	5.7	3.9	1.0	18.4	10.0
8-12 years	16.5	17.1	12.6	23.5	14.6	35.6	78.8	40.8
12-40 years ...	80.1	80.1	74.8	70.8	81.5	63.4	2.8	49.2
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE VIII. NUMBER OF PEAR TREES OF EACH DISTRICT AND OF ENTIRE VALLEY BY AGE CLASS

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
1-8 years	114	127	12	2	......	......	43	298
8-12 years	116	84	3	......	......	......	28	281
12-40 years ...	312	66	29	......	5	......	......	412
Totals	592	277	44	2	5		71	991

TABLE VIII-a. PERCENTAGE OF PEAR TREES OF EACH AGE PLANTED IN EACH DISTRICT

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
1-8 years	38.2	42.5	4.0	0.7	......	......	14.6	100.0
8-12 years	59.0	29.9	1.0	......	......	......	10.1	100.0
12-40 years ...	75.7	16.0	7.0	......	1.3	......	......	100.0

TABLE VIII-b. PERCENTAGE OF PEAR TREES OF EACH AGE CLASS IN EACH DISTRICT

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Florence	Penrose	Entire County
1-8 years	19.2	45.8	27.2	100.0	......	......	60.5	30.1
8-12 years	28.0	30.3	6.8	......	......	......	39.5	28.3
12-40 years ...	52.8	23.9	66.0	......	100.0	......	......	41.6
Totals	100.0	100.0	100.0	100.0	100.0		100.0	100.0

TABLE IX. PERCENTAGE OF PLUM TREES OF EACH AGE CLASS IN EACH DISTRICT

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Flor-ence	Penrose	Entire County
1-8 years	10.4	27.5	62.8	......	18.4	......	26.4	20.2
8-12 years	56.7	37.3	21.2	16.1	41.9	......	73.6	49.8
12-40 years ...	32.9	35.2	16.0	83.9	39.7	100.0	......	30.0
Percentage Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE X. PERCENTAGE OF CHERRY TREES OF EACH AGE CLASS IN EACH DISTRICT

Age Class	Lincoln Park	East Canon	Four Mile	Orchard Park	Park Center	Flor-ence	Penrose	Entire County
1-8 years	28.7	28.7	12.8	11.7	36.8	18.4	78.4	63.7
8-12 years	42.2	57.0	71.7	23.1	34.5	55.8	21.6	28.5
12-40 years ...	29.1	14.3	15.5	65.2	28.7	25.8	......	7.8
Percentage Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

GRAND TOTALS

Number of acres in fruit trees	5,668.16
Number of fruit trees of all kinds	266,729
Number of orchards	687

Distribution of Trees by Age Class—

Age 8	77,786
Age 8-12	97,456
Age 12-40	91,487

Condition of Orchards—

Fair	321
Good	216
Poor	150
Total	687

ACKNOWLEDGMENT

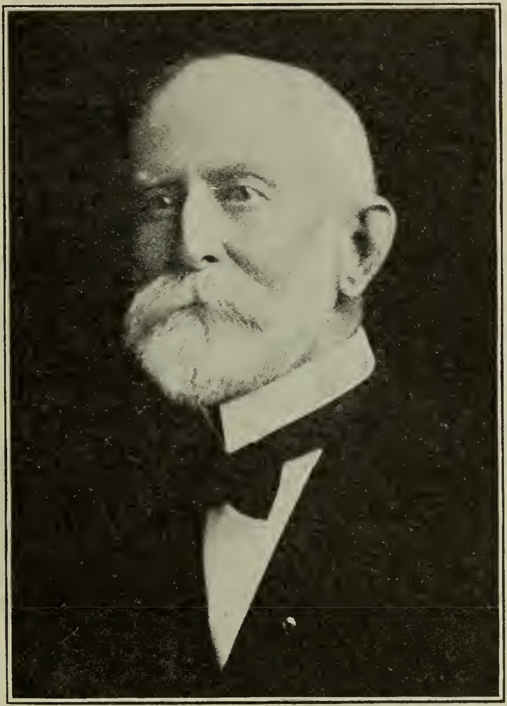
The authors are greatly indebted to Mr. Ralph R. Jeffries, county agricultural agent of Fremont County, for his valuable help in locating the orchard districts and in furnishing office facilities.

We wish at this time to thank the orchardists of Fremont County who have so kindly and so heartily co-operated with us in gathering information included in this bulletin. Without their hearty co-operation, it would have been impossible to conduct the work successfully.

HISTORICAL DATA

The first apple trees in Fremont County were planted by William Lee in 1862. The spring flood of that year on Spring Creek where the orchard was located destroyed the planting, but the orchard was re-set the following spring, 1863.

Jesse Fraser planted the first orchard at Florence in 1866, and the same year established a nursery. From this nursery Captain B. F. Rockafellow bought his trees for the first extensive planting at Canon City in 1869. This planting date marks the starting point of commercial fruit growing in Fremont County.



CAPTAIN B. F. ROCKAFELLOW

When one looks back upon the extensive and costly planting of Captain Rockafellow in a new and untried fruit section, we must admire not only the foresight and wisdom, but also the daring which he displayed in this enterprise. Subsequent development has amply justified Captain Rockafellow's faith in the district, and Fremont County and the State of Colorado owe him deep gratitude for the services which he rendered toward the development of fruit growing in the State.

Captain Rockafellow not only takes pride in the growing of the first orchard, but he has always been a leader in the development of fruit growing in other sections of the State, principally thru the State Horticultural Society, which he helped to organize September 30, 1880. He has always been an active member of the Fremont County Horticultural Society, and has, more than any other man, labored in the interest of fruit growing in his own county and in the State.

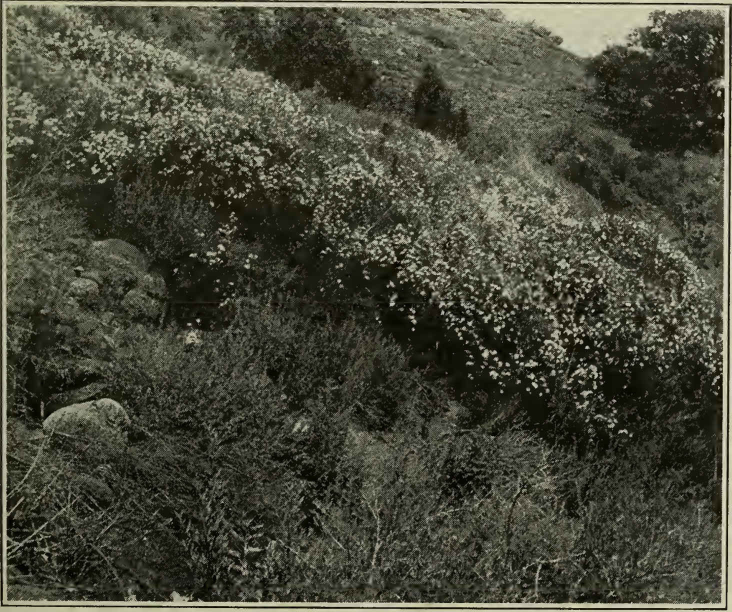
1b
p.4

Bulletin 255 January, 1920

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

WHORLED MILKWEED
The Worst Stock-Poisoning Plant in Colorado

By W. L. MAY, Assistant Botanist



A bad patch of milkweed on a rocky hillside just below an irrigation ditch.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

NAT. HIST.

Colorado Agricultural College

FORT COLLINS, COLORADO

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WHORLED MILKWEED

The Worst Stock-Poisoning Plant in Colorado

By W. L. MAY, Assistant Botanist

The investigative work on the whorled milkweed in Colorado, carried on during the past two summers, has demonstrated that this plant is the most dangerous poisonous plant in the State, both because of its toxic properties and because of its extreme resistance to eradication measures. The importance of the problem justifies continued effort and expense on a larger scale than has so far been employed. The problem is not yet solved, but enough has been done to justify placing before the stockmen and farmers of the State the results of the work so far done.

LOSSES CAUSED BY WHORLED MILKWEED IN COLORADO

It has long been known to medical science that the various species of *Asclepias* possess toxic and medicinal properties, and the members of the genus have long been viewed with suspicion as being poisonous, but it is only recently that particular attention has been directed to the species under discussion as being a very dangerous stock-poisoning plant. At the present time it is definitely established that *Asclepias galioides* has been responsible for very heavy annual losses of sheep, cattle, and horses in Western and Southwestern Colorado, and it is suspected that the plant has been the cause of some unexplained losses in Huerfano and Las Animas Counties and in the irrigated sections along the Arkansas River from Canon City to the state line.

The earliest case on record at this station of the heavy loss probably due to "whorled" or "bedstraw milkweed" is that of the loss of 85 head of lambs by Mr. W. E. Ryman, a sheepman near Colona, Colorado, in 1909. These lambs were poisoned in an orchard containing much of the milkweed and Mr. Sam Phillips, a neighbor of Mr. Ryman, reported to the writer in 1918 that the state veterinarian at that time suspected the milkweed as being responsible.

The attention of the Colorado Experiment Station was first called to this plant in 1915 by Dr. A. P. Drew, of Grand Junction, who reported that he had strong evidence of the poisoning of stock from milkweed fed in the hay. Dr. Drew later reported that a large percentage of his winter practice is from stock poisoning due to this cause. About this time Dr. Walter Craig, a veterinarian at Paonia, also sent in samples of the plant and pronounced them as being suspicious.

Among the cases of large losses that have come to the notice of this station in the last few years are the following:

On Rogers Mesa, near Hotchkiss, Colo., in the fall of 1917, 44 head of steers belonging to the Bar K Cattle Company were lost over night in a pasture. These steers had been driven a distance of about 20 miles from the range and were turned into the pasture hungry. In the morning 44 head of the animals were found dead. Whorled milkweed was present in considerable quantities and Dr. Craig, of Paonia, reports that this plant was doubtless responsible for the poisoning.

Near this same place the Bennett brothers, in June, 1918, lost 350 head of sheep. The following is taken from Bulletin No. 246 of this station, page 4. "This case was between Hotchkiss and Paonia, Colorado. A herd of 1,700 sheep had been ranged in the cedars and sagebrush. On June 2 these were turned into an old, abandoned 10-acre orchard for one day for the purpose of shearing and dipping. The orchard was enclosed. They were left in the orchard about eight hours, and in the evening driven out of the orchard to their bedding grounds in the cedars about 100 yards away. Between that evening and the following noon 350 sheep died. Inspection of this old orchard was made on June 14. It was very thickly grown up to whorled milkweed; in fact, there was very little succulent vegetation of any kind in the enclosure except the milkweed. Inspection showed that practically every plant had been eaten down, and that that the growth present, was that made between the dates June 2 and June 14. The orchard stood in the midst of a cedar and sagebrush growth, and examination showed no milkweed in this native association. It is clear in this instance that the sheep were forced to eat milkweed, and they came there from their range hungry."

The following case came under the author's observation, five miles north of Cortez, Colorado:

Sheep which were lambing were kept in a dry pen for two weeks and were fed on nothing but bright, green alfalfa hay. About 9 o'clock on the morning of June 8, a number of these sheep with their lambs were taken from one pen and driven about 75 yards along a bare road to a corral previously unused. The sheep were not fed as usual at noon, and the owner did not go to the corral until about 4 p. m. At that time 15 of the sheep were dead and others were sick. Only the old sheep that could eat were poisoned; none of the suckling lambs were affected. A thorough examination of the corral, which was about 2 acres in extent, showed that the only vegetation present was a few scrub pinon and cedars, one or two dried up sage bushes, and in one corner a patch of milkweed about 30'x50' in extent. This milkweed had been about half eaten off, and it could not have been more than two or three inches high, so that a comparatively small amount was eaten by the sheep which were killed.

Near Grand Junction, in August, 1918, horses which were being fed from a stack of hay cut from a new field were dying with typical poison symptoms. Other horses having the same care but which were fed from other hay were not affected. This particular stack of hay was found to contain large quantities of whorled milkweed, and an examination of the field from which it was cut showed that about one-third of the ground was infested with the milkweed. In all, six head of horses were poisoned from the stack of hay and when the milkweed was picked out of the alfalfa, or stock changed to other hay, the losses stopped.

On a main sheep driveway near Cortez, Colorado, there occurred a series of heavy losses which have become historical in the records of the investigations on milkweed in Colorado. The place where these losses occurred has been named Death Valley by the stockmen in that section of the country. It is on the driveway along which at least 50,000 sheep are moved annually between the winter and summer ranges. It is situated close to water and to Cortez, forming an ideal place to camp, so that bands were often held there over night. These losses were all of sheep, although there is strong evidence that seven head of cattle were poisoned while being driven through this area.

The first loss of any size at this place was that of 30 head of sheep owned by Mr. Hiram McEwen, of Cortez, Colorado. This was in 1915.

In the fall of 1916, James Gawith of Cortez, drove 1,100 head of sheep from the summer range down thru Montezuma Valley to the winter range. This band was stopped at Death Valley, and held for a time. Within a few hours after leaving the bed grounds 576 head died. The symptoms were so nearly like those from strychnine poisoning that many people at that time suspected that the sheep had been deliberately poisoned by alien enemies.

In early June, 1917, Mr. W. T. Fowler was driving a band of 1,100 sheep thru Montezuma Valley on their way to the summer range. The sheep, according to Mr. Fowler's statement, had been on the driveway for four days, and had had only about one-fourth rations. When they reached Death Valley another owner ahead asked Mr. Fowler to hold his band an hour or two so as to prevent the two bands from mixing. The sheep grazed over the area since found to be badly infested with milkweed for about two hours, and at the end of that time they began to die. Two hundred and twelve head were dead before night.

In November, 1917, Mr. R. E. Walker pastured 900 head of ewes across the milkweed-infested field. Whorled milkweed constituted about all of the available forage at the time. The band was held on this patch for some time and 780 head died within twelve hours with the same typical poisoning symptoms shown by the sheep previously lost at this place. Figures 1 and 2 do not show the sheep after they were dragged together, but as they actually fell. Four hundred were pulled out of the main road to allow cars to pass.

Figs. 1 and 2—780 head of sheep out of 900 were poisoned here in one day.

This series of losses at one place and under practically the same conditions led to the sending of the writer into the field in the spring of 1918 to establish the identity of the plant causing the trouble and to work out its distribution and efficient methods of control and eradication.

This work has been carried on during the summers of 1918 and 1919 and the data so far obtained has shown that the milkweed problem is one of considerable importance both from the standpoint of stock-poisoning and from the difficulties of eradication which it presents. It deserves the continued attention of stock owners, farmers, and experimental workers.

HOW IT MAY BE IDENTIFIED

The plant under discussion belongs to the group of milkweeds having verticillate or whorled leaves which are linear in outline. There are three common members of this group, *Asclepias verticillata, A. galioides* and *A. pumila*. *A. pumila* is much smaller than the other two, seldom being over a foot high, and having very fine leaves. (Fig. 3). *A·galioides* and *A. verticillata* are much more nearly alike. In Bulletin No. 246 of this Station, published in July, 1918, the plant which has been responsible for the losses of livestock in Colorado was called *A· verticillata*. This bulletin was issued as an information bulletin to call attention of stockmen to the poisonous nature of the

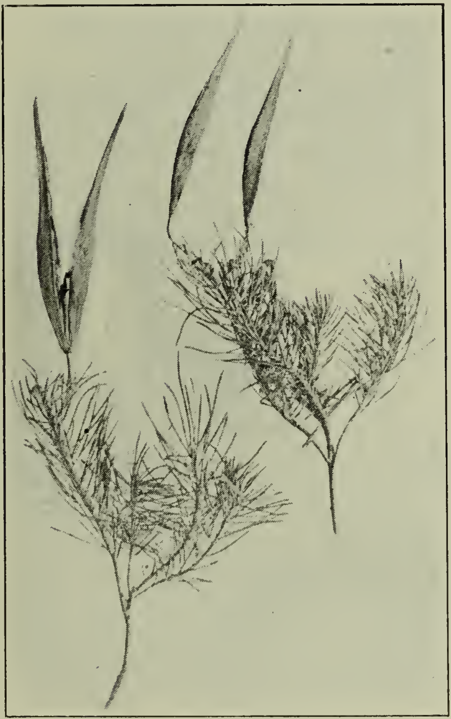


Fig. 3—Low milkweed (**Asclepias pumila**) not known to be poisonous.

plant, and before very much investigative work from the botanical standpoint had been done. Further investigations have shown that *Asclepias galioides* is probably the species responsible for the heavy losses of livestock in Colorado. *A. verticillata* does not occur in large quantities in the State, tho it is present, nor is it known definitely at this Station whether or not the two species, *A. verticillata* and *A. pumila* are toxic. The determination of the toxicity of these two species is part of the work planned at this station.

Although the common name "whorled milkweed" more properly belongs to *Asclepias verticillata,* it has been considered advisable to retain the name whorled milkweed, inasmuch as it has become so widely used in this State in reference to *A. galioides.* Britton and Brown give the name "bedstraw milkweed" to the latter.

Asclepias galioides is a perennial from horizontal, underground rootstocks. These spread in all directions at distances from an inch to a foot underground. These underground rootstocks are usually slender, being from 1-16 inch to 1-2 inch in diameter, and may grow underground for several feet from the main plant. Occasionally taprooted specimens are found, but these are the exception. Figures 4 and 5, illustrate the type of underground growth. The nature of spreading results in characteristic, thick, circular patches. The roots and rootstocks may be so thick as to form practically a turf in the upper several inches of soil. This turf is very tough and exceedingly hard to plow. The seedlings have a single, slender taproot during the first season.

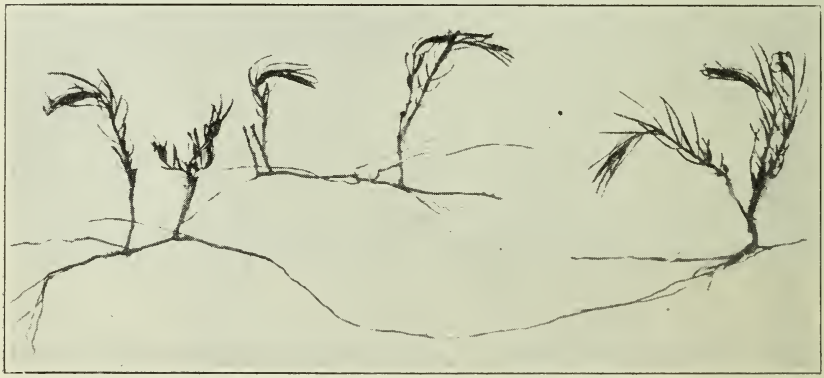


Fig. 4—The plant has a very effective method of spreading by creeping horizontally underground.

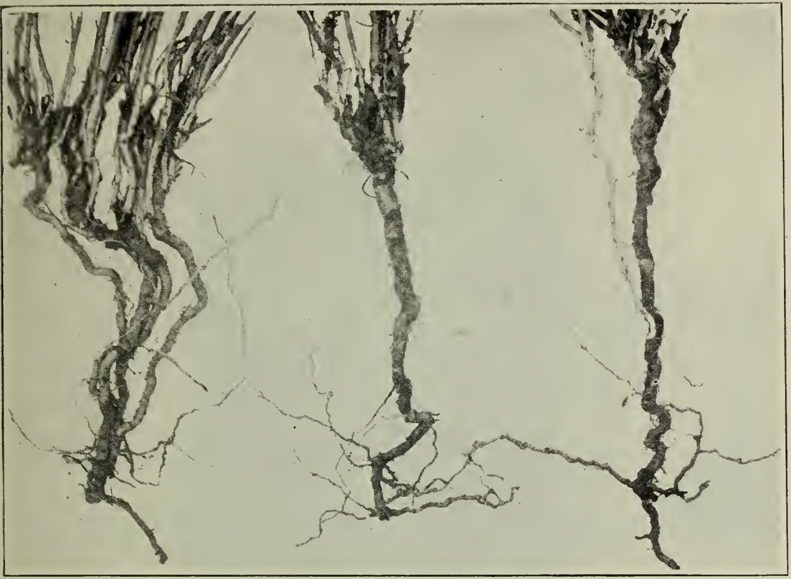


Fig. 5—The rootstocks of whorled milkweed may extend to considerable depth in the soil.

The stems grow in clumps from a crown and are unbranched. They are smooth, except for a minute pubescence, and light green in color. The bast fibre is strong and abundant. Their height varies from 14 inches to 4 feet. The leaves are in whorls, almost invariably three well-developed at each joint of the stem, tho four is not an uncommon number. Never has the author seen a stem of A. *galioides* in Colorado with more than four well-developed leaves at each joint, but the number is usually constant in any given stem. In the case of seedlings, (Fig. 6) the leaves are **opposite** for the first seven to fifteen nodes and then the whorl of three begins. The leaves are narrowly linear from 1¼ inches to 4 inches in length and usually not over about ⅜ inch wide. The margins are somewhat revolute. They have a slightly drooping appearance in contrast to the stiff, upright, position of leaves of *A. verticillata*. The color is a light, slightly bluish green. Figure 7 gives a very good idea of the general appearance of the plant.

The flowers are mostly borne in axillary umbels on pedicels from ½ inch to 1 inch in length and with from twelve to twenty flowers in a group. The individual flowers are greenish white. A group of blossoms at a distance resembles nothing closer than

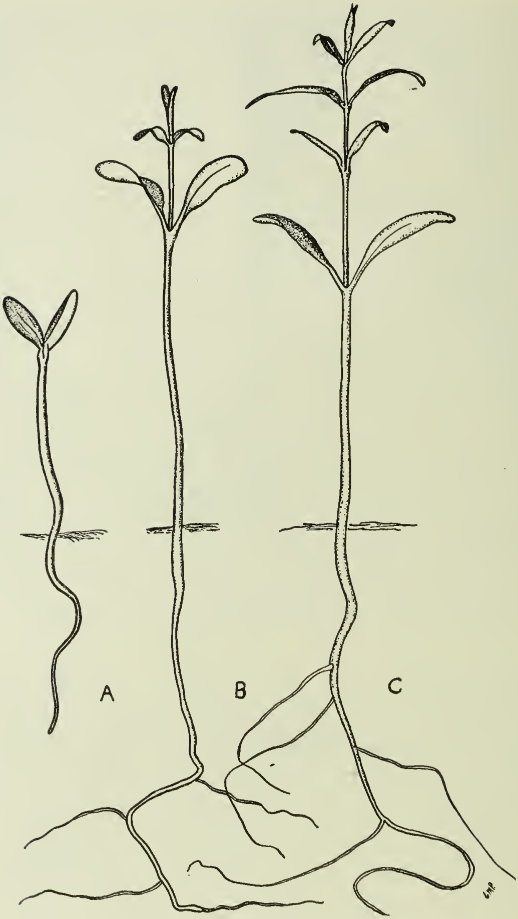


Fig. 6—Seedlings of whorled milkweed. A. Seven days after planting. B. Twenty-one days after planting. C. Twenty-eight days after planting. Note that the first foliage leaves are in pairs.

a small group of onion blossoms, tho in the case of the milkweed the clusters of blossoms are borne in axils of the leaves as well as terminally (Fig. 8).

The pods are erect, long-pointed above and short pointed below. They may be borne singly or in clusters, as shown in Figure 9. Thev are commonly from 2½ inches to 4 inches long. Each pod is filled with closely packed, flat, reddish-brown seeds to each of which is attached a number of white silky hairs which facilitate spreading to a marked degree (Fig. 10).

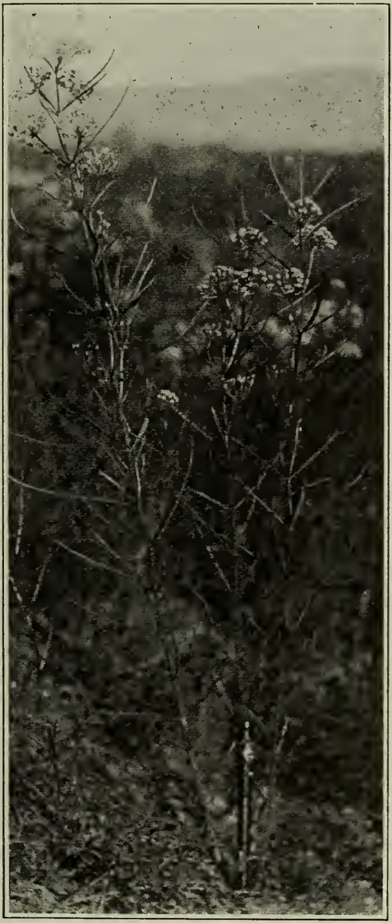


Fig. 7—A typical whorled milkweed plant in late blossoming stage.

Figure 11 is that of a plant very commonly supposed in this State of the poisonous milkweed. It is *Asclepias speciosa*, the showy milkweed, and is not the one responsible for losses of livestock. Note in this plant the large, broad leaves. The blossoms are lavender in color and much larger than in the whorled milkweed. The pods in the showy milkweed are also larger and covered with protuberances.

DISTRIBUTION IN COLORADO

The map on page 16 (Fig. 12) shows the present known distribution of whorled milkweed in Colorado. By far the worst

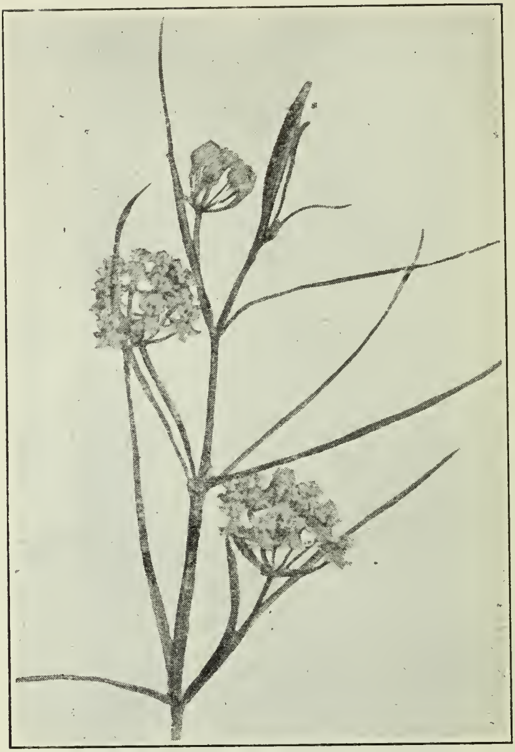


Fig. 8—Axillary clusters of blossoms of whorled milkweed.

infestation is on the Western Slope, particularly in Mesa County. On the Eastern Slope the present known distribution is confined to isolated spots in Las Animas and Huerfano Counties and thru the irrigated sections of the Arkansas Valley from Canon City to the state line. In all probability there are other infestations in the State not shown on the map. It is also very probable that there are other regions in addition to those shown on the map where losses have occurred. From the facts at present known about the plant there is no reason why it could not occur in any of the irrigated sections of the state.

The milkweed is known to be present in quantities sufficient to cause trouble in Utah and New Mexico, and recently a communication fom an official of the United States Reclamation Service states that the milkweed occurs in large quantities on the Truckee-Carson Project near Fallon, Nevada, and is suspected of causing losses of livestock in that region.

WHERE TO LOOK FOR IT

Thruout the State the milkweed is confined almost entirely to the irrigated sections. In the non-irrigated lands there have been found a few patches, but these nearly always occur where the soil has been broken, or where water from heavy rains collects for a considerable time during the year. The plant does not require much water after once being established, but is very slow in getting started and requires moist conditions during the first part of its life. The seedling is very easily killed, but after the plant is well rooted it will withstand extreme conditions of drought. The worst infestations from the eradication standpoint occur on hillsides below ditches where the seep keeps a water level within a foot of the surface, or where the seep may reach the top of the ground. In the latter case, the milkweed does not

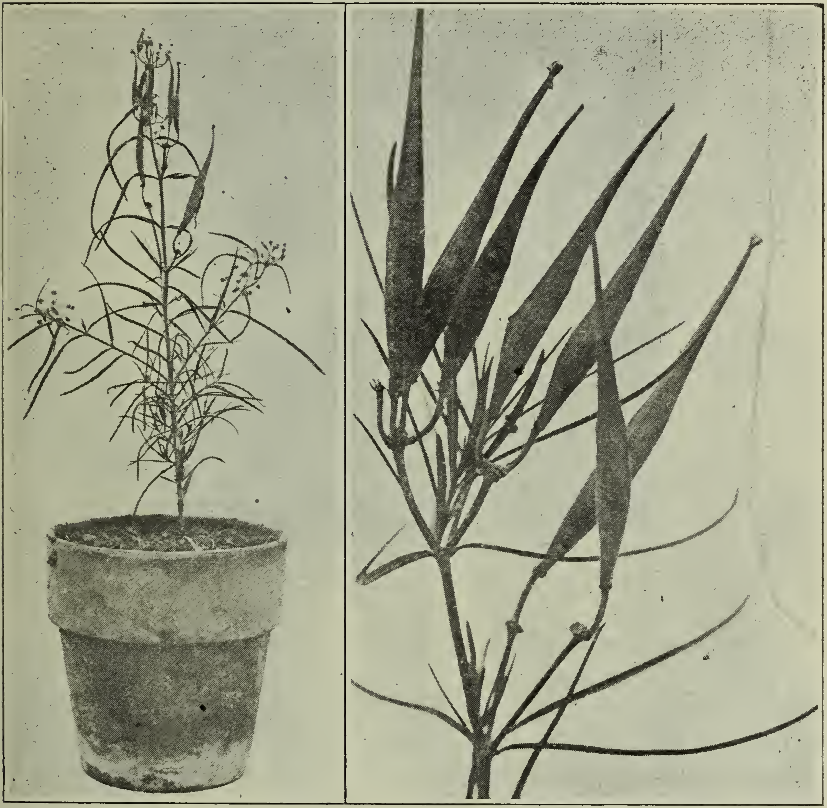


Fig. 9—The pods are erect and pointed and may be borne singly or in groups.

grow directly in the seep, but around the moist edges and back to the extremely dry land.

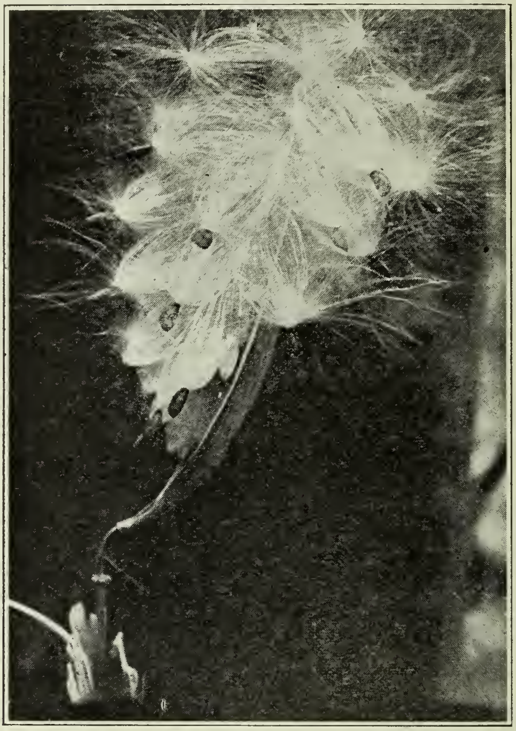


Fig. 10—A single pod showing large numbers of seeds escaping.

In regions where the infestation is comparatively new the milkweed is found along the ditch banks in isolated, heavy patches from a few square feet in area to a quarter of an acre or more in extent (Fig. 13). **No other plant** grows where the milkweed is *well established.* Below a ditch bank near Paonia, an area of foxtail (*Hordeum jubatum*) half an acre in extent was driven out by whorled milkweed in three years. In oat fields, where there were patches of milkweed and the field was plowed in the spring, no oats grew in the areas occupied by the stands of milkweed, despite the fact that the surrounding crop was very heavy.

This species has been found on several types of soil, from a very light sandy loam to a heavy clay adobe, and from fine soil to a soil composed largely of gravel and rocks. It does best, how-

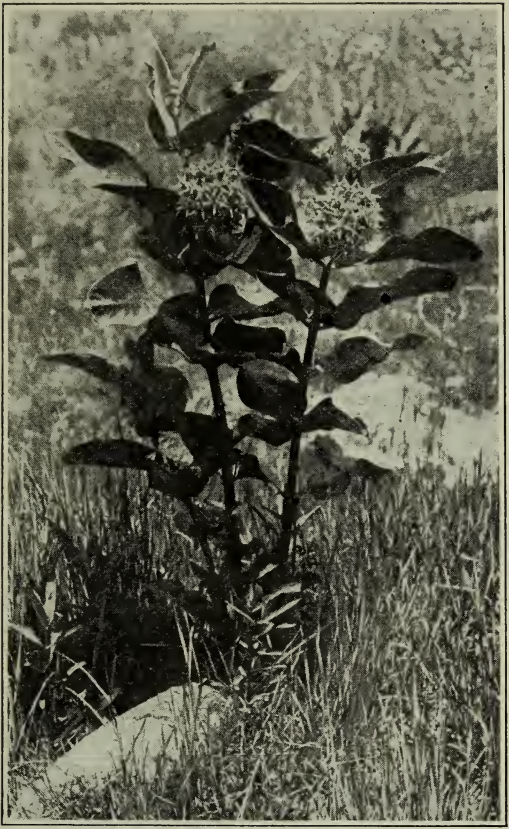


Fig. 11—Showy milkweed. This plant is often supposed to be the poisonous milkweed. It is not known to be poisonous.

ever, on the heavier clay type. It does especially well on the red clay loam of La Plata and Montezuma Counties and on the heavy, gray clay of the North Fork and Grand River valleys. It is not so well adapted to the lighter sandy soils. Alkaline soils produce a better growth than do acid soils, although from the salt spray experimental work at Cortez, it appears that the alkalinity can be raised with common salt at least to such a percentage as to kill the milkweed without inhibiting the growth of such plants as Russian thistle.

The altitudinal limit for Colorado seems to be somewhere in the neighborhood of 7,500 feet. Plants found at a little below this elevation did not appear to be as thrifty as plants at lower elevations, nor have any extensive infested areas been found above

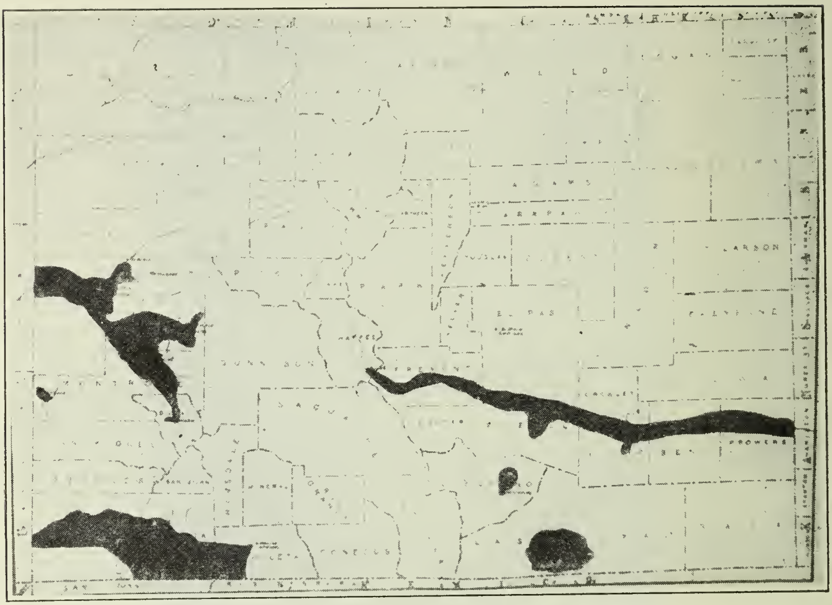


Fig. 12—Map of Colorado giving present known distribution of whorled milkweed.

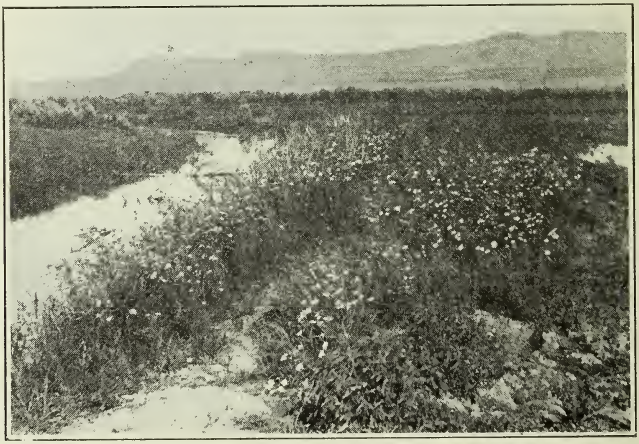


Fig. 13—In new regions the milkweed occurs in patches on the ditchbanks.

7,000 feet. The altitudinal range of best growth in this State is from about 5,000 feet to 6,500 feet.

The plant is commonly found along ditch banks, roadways, and railroad right-of-ways, in fence rows (Fig. 14), and abandoned fields and in orchards only partially clean cultivated. (Fig. 15). Where the infestation becomes bad it will make its way by the underground rootstocks into solid stands of blue grass or into alfalfa fields.

HOW IT IS SPREAD

The seed of this species, like all of the milkweeds, is admirably fitted for wide and easy distribution.

The agencies, in the probable order of their importance, that are responsible for the spreading of the seed are: (1) Water, (2) wind, (3) railroads, (4) animals.

Water.—In every infested area so far observed it has been clearly shown that irrigation water plays an important role in carrying the milkweed seed. In territories newly infested, the patches are always found along the laterals. This was well demonstrated in the West Paradox Valley. Four years ago sheep were lost in the west and upper end of the valley and at the time whorled milkweed was suspected by Mr. John Rohwer. He has been watching this plant since then, and has noted the gradual spread of it over the ranches in the upper end of the valley. Last summer the infestation had spread several miles down the valley and the lower patches are largely along irrigation laterals or in

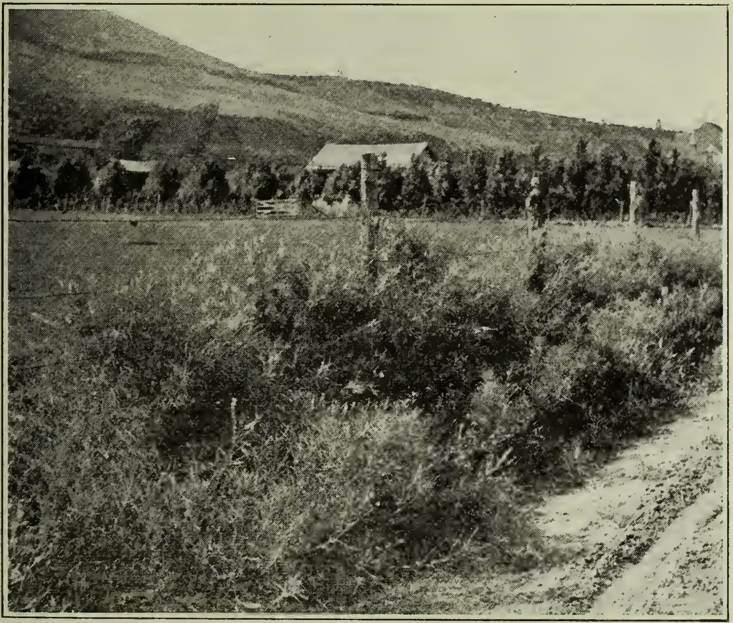


Fig. 14—The fence row is a common place for this plant to be found.

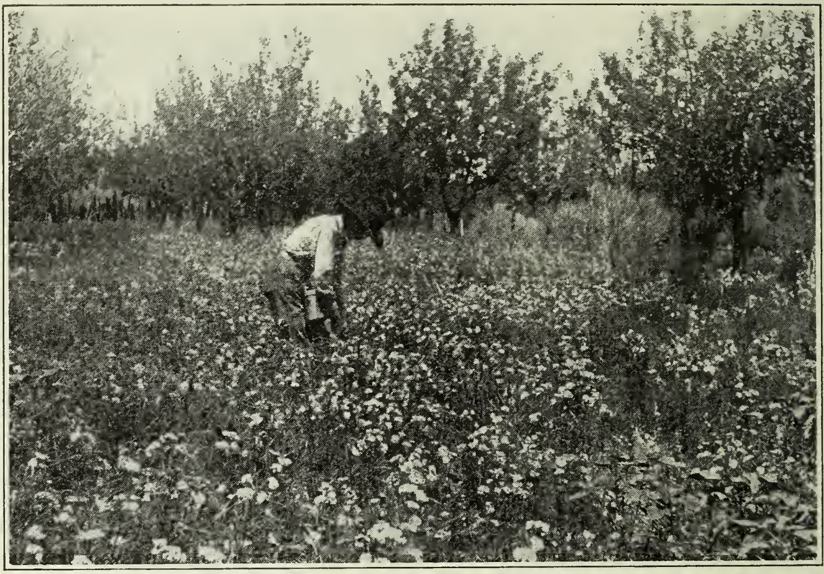


Fig. 15—An uncultivated orchard taken by milkweed.

irrigated fields or orchards. These same observations are duplicated in other sections of the State.

Wind.—The buoyancy of the seed, due to the lightness of the seed itself, and to the parachute of silky hairs, makes it very well adapted to dispersal by wind. Everyone is familiar with the ease with which milkweed seeds are carried on a light breeze. It is not probable that seeds are carried in this manner as far as they are carried in large irrigation laterals, but the wind undoubtedly serves to cause a great deal of dispersal. The dispersal by water is undoubtedly the most effective because it not only carries the seed long distances but always places them in a suitable place for germination.

Railroads.—This agency is important not so much from the standpoint of numbers carried as from the fact that it has probably been responsible for the establishment of the weed in entirely new territories. The railroad right-of-way is a very common habitat of the milkweed. This does not, of course, argue that the railroad is responsible for the carrying of all the seed that has been scattered along the right-of-way. Wind might just as easily be responsible for the carrying of much seed to the embankments or cuts along the railroad but there have been a number of cases of occurrence of the weed at railroad switches, especially at points where stock are unloaded, that are very convincing circumstantial evidence that the weed has become established at these points from seed carried on the hoofs or in the tails or coats of animals that have been unloaded from the cars. A very noticeable case of this kind is the occurrence of a single isolated patch of the milkweed at Jay spur on the D. & R. G. narrow guage above Ridgway in Ouray County. So far as could be determined by a rather careful survey of the Dallas Valley, this is the only patch present. The closest known infestation is in the Uncompahgre Valley around Colona and Uncompahgre, about fifteen miles below Jay spur, and, therefore, the seed could not have been carried by water. Many cattle are loaded in the Colona and Uncompahgre section and shipped up the narrow gauge. Occasionally some of these are unloaded at Jay spur. The most obvious explanation of the spread of the milkweed in this case is the carrying of the seed by animals in the cars.

Other places where milkweed occurs under very similar conditions as stated above are at stockyards near Dolores, Colorado, and at Cucharas Junction in Huerfano County. There can be no doubt that the milkweed is being carried to new territories by this means.

Animals.—The probable carrying of seed by animals being shipped has been noted above in connection with dispersal by railroads. Since the seed is not fitted with clinging structures it is not likely that animals are a very important factor in carrying milkweed seed, but a very interesting case came under the writer's observation in Archuleta County the past summer. Milkweed occurs in this county along the main sheep driveway to the summer range. There is no other infestation in this section except in the driveway, where the animals have trampled the ground. It is known that the lower winter and spring ranges are in bad milkweed areas, and it is probable that in this case the seed has been carried in the wool or hoofs of the sheep and trampled into the soil.

Possibility of Dispersal In Crop Seeds.—While no definite cases of the establishment of new patches through impure seed have come to the attention of this station, the writer can see no reason why such has not been the case. There are many grain fields in which the milkweed produces seed before the grain is cut and the writer has seen bins of grain containing milkweed seed. One case has been reported of a man feeding oats containing a large quantity of milkweed seed with the death of a horse from typical poisoning symptoms as a result. Milkweed seed is undoubtedly present in some grain that is harvested in this State and it is only necessary that this seed be sown for the plant to become established. There has been started a practice in some parts of the State of allowing alfalfa fields too badly infested with milkweed to be used for hay, to go to seed. This procedure cannot be too strongly condemned, because while the milkweed seed may be cleaned from the alfalfa, these fields will become breeding grounds for seed to be blown by the wind and carried by water. Furthermore, seed buyers will learn to discriminate against such sections, and their sale of seed will be injured.

GERMINATION OF MILKWEED SEEDS

The accompanying table shows the germination of whorled milkweed seed gathered in the Montezuma Valley in August, 1918. Part of this seed was gathered from pods which had matured on the plant, the rest from pods which were not matured at the time the plants were cut, but which burst open after the plants had lain on the ground for a week or ten days. There was no difference in germination between these lots of seeds. These were produced in an extremely dry and unfavorable season.

TABLE I

Germination of Seeds of **Asclepias galioides**

Date Begun	Per Cent Germination					
	3 days		5 days		14 days	
	A	B	A	B	A	B
Sept. 17, 1918	30	42	46	59	57	64
Sept. 17, 1918	28	31	67	63	71	65
Oct. 16, 1918	91	42				
May 6, 1919	93	92	93	92	93	92
May 20, 1919	93	93	94	94	94	94
June 3, 1919	95	97	96	97	96	97
June 16, 1919	94	95	94	95	94	95
June 30, 1919	95	98	95	98	95	98
July 14, 1919	92	96	92	96	93	96
July 28, 1919	95	97	95	97	95	97
Aug. 11, 1919	96	95	97	95	98	95
Aug. 25, 1919	95	93	97	94	97	94
Aug. 8, 1919	96	98	96	98	96	98
Aug. 22, 1919	98	98	98	98	98	98

NOTE—All lots tried in September and October, 1918, germinated over 90 per cent at the end of 20 days.

The germination tests were carried out to answer three questions: (1) What percentage of the milkweed seed is viable? (2) How soon after being shed from the plant are the seeds viable? (3) For how long a time do the milkweed seeds keep their viability?

An answer to the first question was desired in order that some gauge might be had by which to determine the importance of the seed in dissemination. Fitted as it is for dispersal, the milkweed requires only that an appreciable percentage of the seed will germinate in order for it to become easily established in a new territory. The results as shown in Table I prove that milkweed seed has a high percentage of germination. It is believed that this is generally true.

The second question as to the period of time which must elapse before the shedding of the seed and the time when germination will begin, arose from certain observations in the field. Altho a close watch for seedlings was maintained thruout the season of 1918, none were found in any appreciable quantities. The writer returned to the station at just about the time that seeds were being shed in 1918, and no observations were made as to the appearance of seedlings in the early fall, but the lack of seedlings early in the year indicated a possibility that the seeds germinate in the fall as soon as they are blown from the plant if they stop in locations favorable as to moisture. The germination tests in the fall of 1918 showed that this theory was entirely tenable. The germination, it will be noted, was rather low, but the lots started on September 17, 1918, and October 16, 1918, showed over 90 per cent. germination at the end of three weeks. The lots on September 17 were placed in the germinator about three weeks after being gathered from the field.

It was at first thought probable that the dry summer of 1918 prevented germination during the season but further observations in 1919 seem to bear out the fall germination theory. Near experimental plots at Paonia, this particular phase was closely observed. A hillside and basin below an irrigation ditch at this point are about 50 per cent. covered with milkweed. The soil surface at this place was moist enough to make a good seed bed during most of the summer season, but it was not until August 25th, **about two weeks after the ripening of the first seeds in 1919,** that any seedlings were found on unoccupied territory. On this date as many as eighteen seedlings per square foot of ground surface were counted, and they would average six to ten seedlings per square foot over a quarter of an acre. These seedlings showed in most cases only the two seed leaves, but before the summer was over, they were 3 or 4 inches high. It seems very probable that many of the seeds germinate in the fall immediately after ripening.

A search for an answer to the third question, however, seems to show that the seeds do not have to germinate in the fall. The table shows that both lots placed in the germinater on September 22, 1919, gave a germination within five days of 98 per cent. This establishes the fact that seeds kept in a dry condition will retain their viability, absolutely unimpaired, for at least a year. Seeds are not usually kept dry in the field, however, and it is possible that the wetting during the winter months may, and undoubtedly does, reduce the germination percentage. It is very possible that this reduction in the number that live over combined with the number that germinate in the fall so reduce the number left the following spring that the seedlings which do come up are so few as to easily escape detection.

When it is taken into consideration that it has been estimated that a single exceptionally large plant of milkweed as shown in Fig. 16, is capable of producing 10,000 to 13,000 seeds and that 90 to 98 per cent. of these are viable, it is readily seen that rapid spreading of the plant depends only on the efficiency of the agents of dispersal as discussed in the foregoing pages.

CONDITIONS UNDER WHICH POISONING OCCURS

The general statement that stock do not like poisonous plants but will eat any other kind of forage in preference to them, is especially true of whorled milkweed. Numerous cases have been observed of cattle being grazed in pastures where milkweed occurs without there being any losses or any symptoms of poisoning, but in every case it has been found that the milkweed grows up and goes to seed, although all other forage may be eaten close

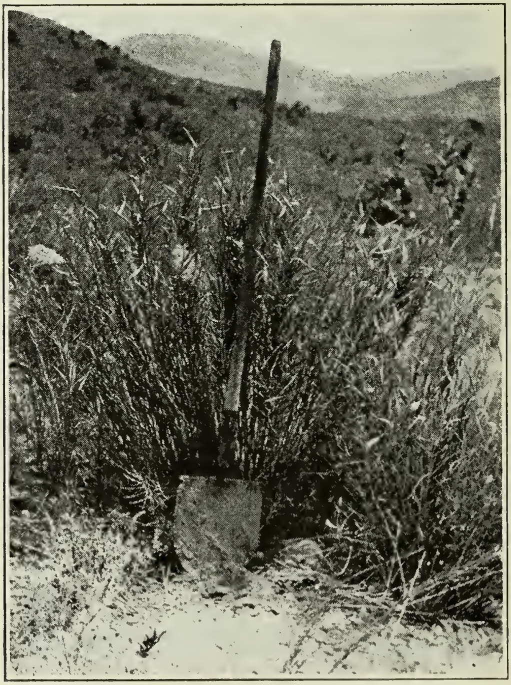


Fig. 16—An exceptionally large milkweed plant estimated to have 13,000 seeds.

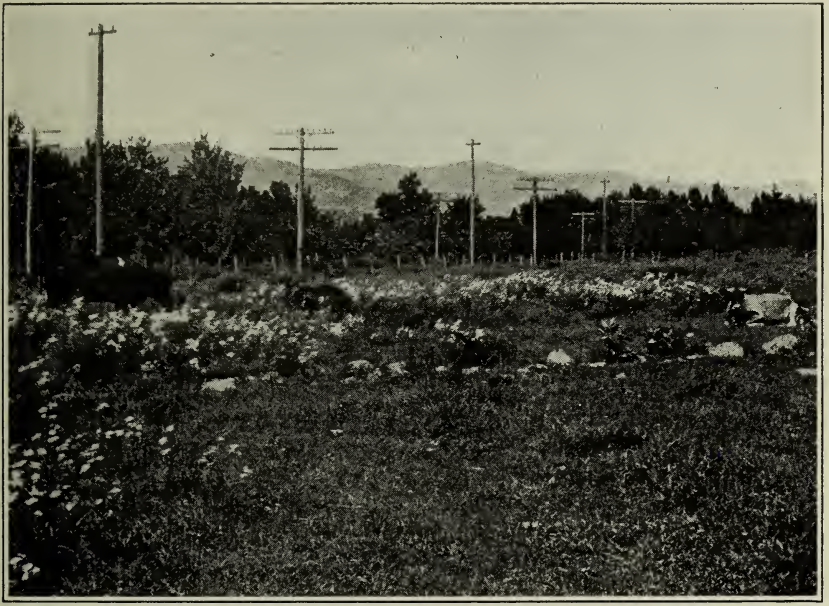


Fig. 17—Stock will eat down everything but milkweed.

to the ground. This is well shown in Figure 17. Note that the grass is eaten down while milkweed is shedding seed. The writer has seen an animal get a mouthful of this plant by mistake, and then drop it immediately. At other times cattle have been observed to go through a thick milkweed patch and pick out a few stray spears of grass without taking any of the milkweed. Roadways along which cattle and horses are being grazed daily will show patches of milkweed in blossom and pod while every other bit of forage is eaten off even with the ground surface. It is very obvious then, that the only conditions under which poisoning from this plant may occur are those where the stock are very hungry and there is an absolute lack of other feed. The one possible exception to this rule is when the milkweed occurs in alfalfa hay and the stock get it along with the alfalfa. Even then animals are likely to nose out the milkweed unless they are very hungry and are eating greedily.

The following conditions are common ones under which losses have occurred:

1. **Along driveways** where other forage has been eaten off and the stock have come onto a large milkweed patch after having been driven a considerable distance. This was the condition

which caused the heavy losses of sheep in the Montezuma Valley near Cortez, and was also responsible for some of the losses on the driveway between Paonia and Hotchkiss in the North Fork Valley.

2. **In pastures** where dairy or farm stock have grazed off the desirable forage, leaving only milkweed in any quantities. This is the condition that existed when the Bar K Cattle Company lost 44 head of steers in one night.

3. **In orchards** which are not being cultivated and which may be used as corrals in which to hold a number of stock either for a short time, or which may be used as pastures. In many of the orchard sections, particularly around Grand Junction and in the North Fork Valley, the owners have abandoned clean cultivation methods with the result that orchards are being taken by weeds. The weed which is most abundant in many cases is whorled milkweed. The use of these orchards for pasturing has resulted in some very heavy losses, the most conspicuous being that of the loss of 350 head of sheep by Bennett Bros. near Hotchkiss, details of which have been previously given.

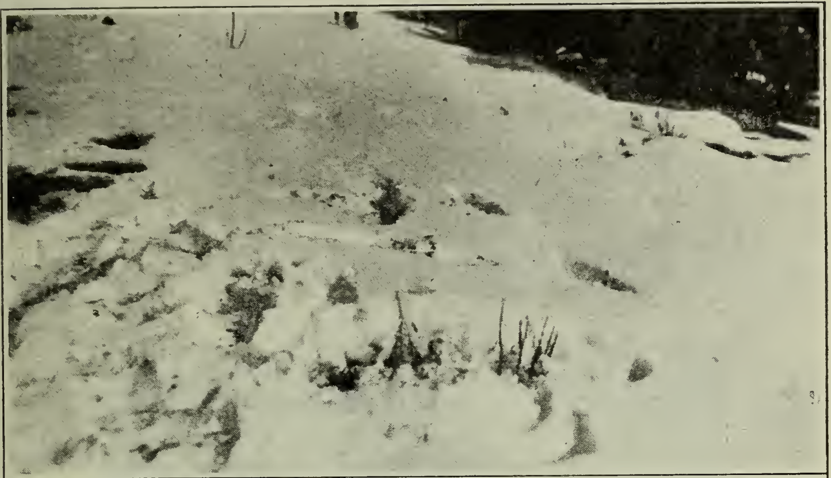
4. When the milkweed is present in sufficient quantities **in the hay** so that an animal can get a toxic dose in one feed. This condition is very common in the section around Grand Junction, and both cattle and horses are being lost in that neighborhood from this source. In one instance six head of horses were poisoned from one stack of hay containing milkweed. Near Whitewater, Colorado, Mr. Fred Burford poisoned 350 head of sheep from one load of hay containing the weed and about 75 or 80 head of these died.

5. In the winter when snow may cover up desirable forage, and **milkweed stems are sticking above the snow.** During the summer stock will eat down everything but milkweed with the result the stalks of the latter wll grow up and will not be covered except by a heavy snow. Under conditions where other forage is covered up, cattle will get hungry and eat the milkweed. Figure 18 shows a small bunch of milkweed under these conditions and shows that the cattle ate the tops. Figure 19 shows the result. Three dead steers are shown in the picture. Seven others died nearby. This was in the early winter of 1919-1920.

Any condition which brings a hungry animal in contact with whorled milkweed is almost sure to result in poisoning.

PREVENTION OF POISONING

From the preceding paragraph the methods of the prevention of poisoning are of course obvious:



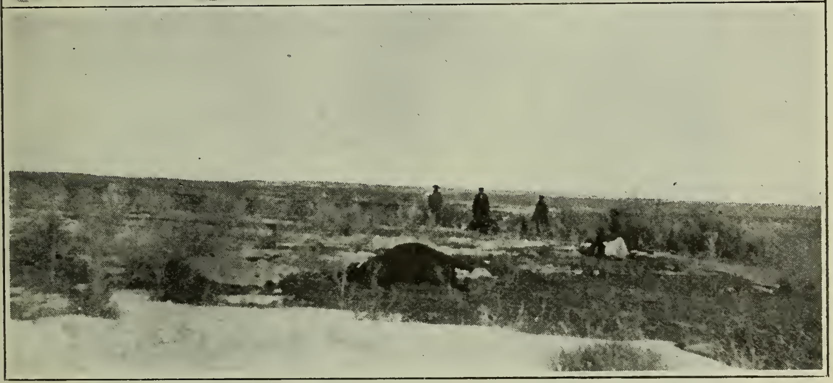


Fig. 18—Above: Milkweed plants sticking above snow eaten off by hungry cattle.

Fig. 19—Below: Three dead animals as a result of eating the milkweed.

1. The stockman should learn to know the plant and should determine if it is present where his stock graze, or in the hay he is feeding. Figure 20 shows a method of sign posting adopted by the State in its publicity and educational campaign on this plant.

2. Hungry animals should be kept away from milkweed.

3. If an infested area must be crossed, one of two things should be done. The milkweed may be cut off along the line of the drive and burned, or the stock may be well fed before crossing the area and the drive kept moving. The latter course does not insure against losses but it reduces the risk to a minimum. It is interesting to note that in the Montezuma Valley in the sum-

mer of 1918 the stock association and county cut off the milkweed along ditch banks and driveways, and that, whereas the the annual loss in the valley for three years previous to this work had been between $20,000 and $30,000, during the winter of 1918-19 and the spring of 1919, no losses occurred in this area. This reduction was as much due to the publicity work which made stockmen acquainted with the plant as to the work done in cutting it off along the driveways.

4. Another precaution is to absolutely refrain from feeding any hay containing milkweed.

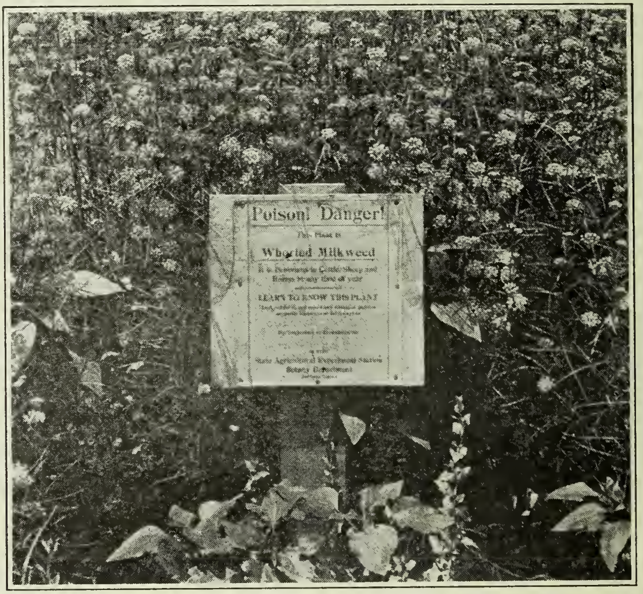


Fig. 20—A sign posted by the State to acquaint stockman with whorled milkweed.

There is no doubt that as long as milkweed is present in any considerable quantities, poisoning is likely to occur, so that if losses are to be absolutely stopped, eradication is the only solution.

ERADICATION

Experimental Work in Montezuma Valley

Experiments were carried on with a view to determining such methods as would fit into general farming practice. Work was begun in the Death Valley area 1 1-2 miles east of Cortez in June, 1918. The soil here is a heavy red clay loam three to four feet deep. There is good drainage. The milkweed occurs in a field which was formerly cultivated in ordinary farm crops, but has been abandoned for a number of years. As previously mentioned this area is on the main sheep driveway thru the Montezuma Valley and has been used as a camping ground by bands going thru. This field, which contains about eleven acres infested with milkweed, was responsible for the loss of 1,600 head of sheep in the years from 1916 to 1918, inclusive.

The County of Montezuma co-operated with the State in the experimental work done on this area during 1918. The 1919 work was carried on by the State Experiment Station in co-operation with the state entomologist.

Plot I. Spraying with Salt Solution.—For this plot a small patch of the milkweed about 10 feet in diameter was used. The application of the spray was made with a hand spray pump. Five gallons of salt solution were used for each application. The strength of the solution was 2 pounds of salt to a gallon of water. The first application was made on June 15, 1918, when the plants were about 3 inches high. The tops were killed back to the ground. On July 8, growth had again been made to a height of about 3 inches, from the roots, and the second application was given. The tops were again killed back. On July 23 the third application was made, when the growth had again reached a height of about 3 inches. On August 23 it was estimated that the growth made between July 23 and August 23 was about 4 per cent. as thick as the original stand, but the shoots seemed healthy, were growing well, and were about 4 inches high. No further applications of salt were made and the milkweed on the plot seemed uninjured except that it had been thinned out.

In the early summer of 1919 no shoots of milkweed made their appearance on this plot and an examination of the soil **showed that a crust** had been formed by the salt in the upper 2 inches of the soil. This crust was dark brown and hard. In this dark stratum of soil the milkweed stems were all blackened and dead, but in the soil below, the roots and rootstocks were alive. **At no time during the summer did a single shoot of the milkweed succeed in making its way thru the salt crust.** One hundred per cent. eradication was obtained on this plot. Figure 21 shows the condition of this plot at the beginning of spraying in 1918 and again in July, 1919. Russian thistle succeeded in becoming established on top of the crust. It must be noted that the season of 1918 was a very dry one, not a single good rain falling from June 1 to September 1. Under these conditions, the salt could not be washed away. Also the plot is removed from an irrigation ditch and consequently is not kept moist. It is not known whether or not this method would prove so successful under humid conditions; but where the summer season is usually very dry it should prove rather efficient, tho somewhat expensive. Thirty pounds of salt were used on this area, containing a little over 75 square feet.

Plot II. Smothering with Tar Paper.—For this experiment a patch of milkweed almost identical with that used for Plot I was selected (Fig. 22). This plot, however, was somewhat larger, containing about 100 square feet. The tops were first cut off when about two or three inches high on June 15, 1918. Tar paper was applied on the same day. The strips of paper were laid flat on the ground and lapped about 1 1-2 inches to insure no entrance of air. The sun effectively sealed these laps. The outside edges of the tar paper were covered over with dirt.

On June 15, 1919, one-half of this tar paper was removed and during the season of 1919, no milkweed growth appeared above ground on this part of the plot. The remainder of this plot was left covered.

This method is recommended for use only on small patches of milkweed on smooth ground where stock do not run and where the ground is not in use. Its advantage is that it needs to be attended to at only one time and can then be forgotten. Care must be taken that the tar paper extends beyond the outer limits of the patch or underground growth will creep out from the main patch.

An interesting modification of this method of treatment was tried out by a farmer near Hotchkiss, Colorado. Wet, heavy manure was piled onto the patch and packed solidly to a depth of from 8 inches to 1 foot. In this way the air was excluded from the patch as effectively as with tar paper and as good results were obtained. **Success with this method as with any other method of eradication, depends entirely upon the thoroughness with which the job is done. Slipshod work is ineffective.** In this method, the object sought is to exclude air from the plants and consequently an airtight cover must be put on the patch.

Grubbing on Dry Land Away from Ditches.—This plot is about 15 feet in diameter and at the beginning of the experiment was covered solidly with the milkweed. The first grubbing was given on July 8, 1918, when the plants were just beginning to bloom. The tool used was a heavy, broad-bladed mattock. A trench was first dug at one side of the patch to a depth

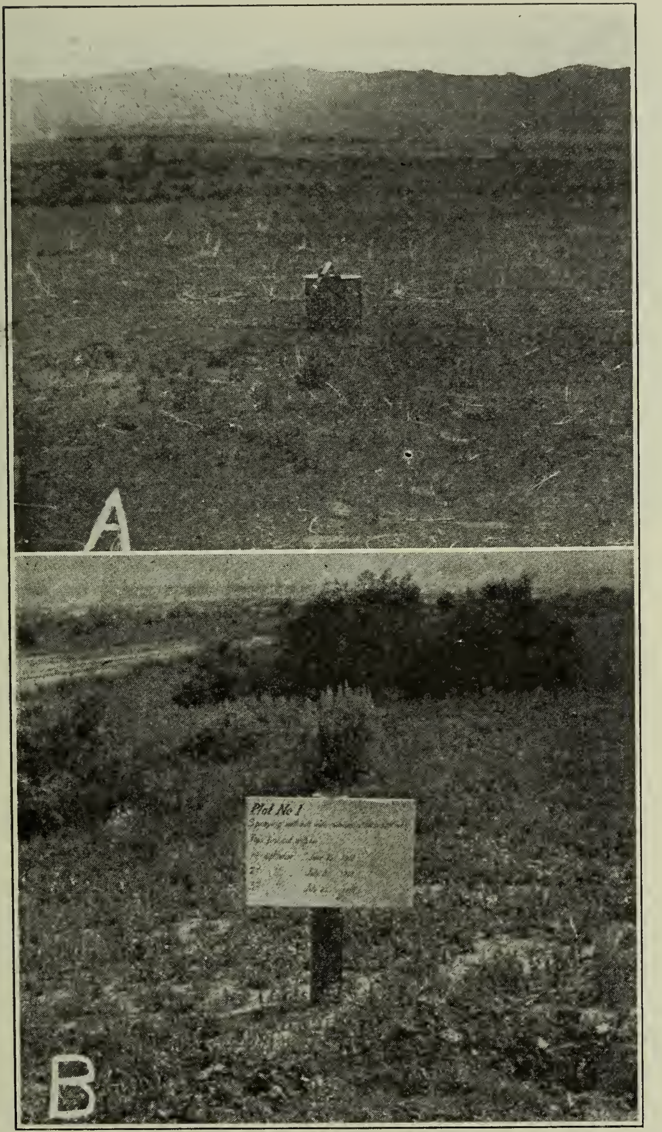


Fig. 21—Plot I. A. June 1918 at start of experiment. B. August 1919 after being sprayed with salt solution. No milkweed present.

of 8 to 10 inches. The trench was dug back a foot or sixteen inches from the outermost green shoot to insure getting beyond the rootstocks creeping underground. This method of procedure

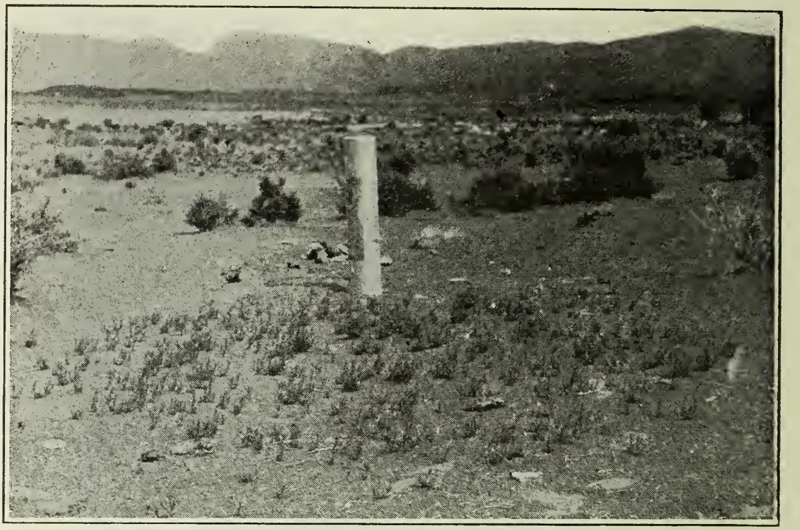


Fig. 22—Plot II. June 1918 before covering with tar paper. Note circular appearance of patch.

gave a bank to work to and by "moving the trench" across the patch all the soil was turned over and the roots and rootstocks removed. The time necessary to do this first grubbing was one hour and a quarter. The time required for grubbing will, of course, vary somewhat with the type and condition of the soil. The soil in this case was worked with comparative ease, although it was dry. The application of the worker will also cause a variation in time required for doing the work.

On July 23 a few plants had come up around the edges from underground parts outside of the grubbed area, and also a few shoots were found in the grubbed part. The entire patch was regrubbed, (time 1-2 hour) and 12 shoots were found on the ground actually grubbed the first time, **all coming from the solid ground below that which had been turned over at the first grubbing.**

During the 1919 season this plot was left untouched. A large stand of other weeds came up on the plot but not over 3 per cent. of the original milkweed stand appeared.

Plot IV. Summer Fallow 1918 Followed by a Cultivated Crop in 1919.—During 1918 this plot was given the following treatment:

Plowed June 15, with a double-disc plow to a depth of 3 or 4 inches.

Doubled disced June 26.
Double disced July 8.
Plowed with tractor 8 inches to 10 inches deep July 23.
Double disced August 26.
Double disced September 20.
Double disced October 15.

The principle followed in this treatment was to keep the plant from having any green leaves during the season; at no time was the milkweed allowed to form any green leaves. As soon as a very few showed through the surface the plot was double disced. The persistence with which the roots continued to send up stalks thru the soil was remarkable. It must be remembered that no rains fell during the period from June 1 to September 1, and that by the latter date the upper 8 inches of soil was as dry and as porous as an ash heap. Every bit of milkweed in this upper layer was dried up and dead but the roots below the furrow slice continued to send shoots to the top of the soil thru the dry dirt until fall. Figure 23 is a picture taken of some of these shoots. In most cases these roots were about the size of ordinary binding twine or smaller, and yet enough shoots were sent up to make the stand as thick as it was originally.

From May 16 to May 20, 1919, this plot was double disced and harrowed. On May 20 part of the plot was planted to potatoes and part to corn. These two crops were treated as follows during the season.

Hoed June 10.
Hoed June 26.
Cultivated three times over July 25.
Cultivated August 10.

The crop was given the treatment of an ordinary farm crop, with the exception that a little more care was given.

The rainfall during the 1919 season was considerably greater than in 1918, but the corn and potatoes were not irrigated. **Despite this treatment the milkweed was thicker in 1919 than it had been at the beginning of the experiment in 1918.** The potato and corn crop were not in any way held back by the milkweed. In fact, due to the summer fallow the previous year, the crops were very good, as shown in Figure 24. The experiment was a good demonstration, proving conclusively that thorough work, begun early and continued thruout the season, and followed the next year by a hoed crop, is inefficient as a means of eradicating milkweed.

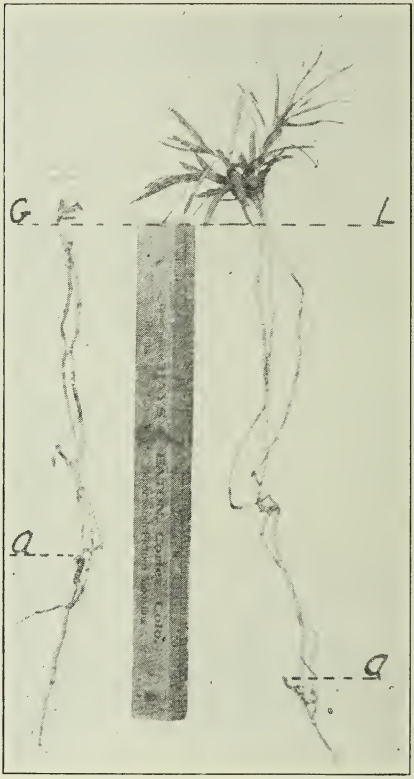


Fig. 23—Growth made on Plot IV from July 20th to August 20th, 1918. A and A are the points at which the old plants were cut off. G. D. is the ground line. The growth was made after the severe treatment outlined in text.

Plot V. Grubbing Along Ditch Banks.—This plot is located a quarter of a mile east of Cortez, on the Cortez lateral. The ground which was infested with milkweed extends along the ditch bank for 50 feet and averages 8 feet in width. The milkweed extended to the water's edge for the full distance. The soil is the heavy, red clay loam, characteristic of the Montezuma Valley, free from rocks and easily worked. The ground was solidly covered with the milkweed at the beginning of the experiment, no other weeds being present. Work was begun at the time the plants were just beginning to form pods, on July 15, 1918. The same method was followed as in Plot III; that is, a trench 8 or 10 in-

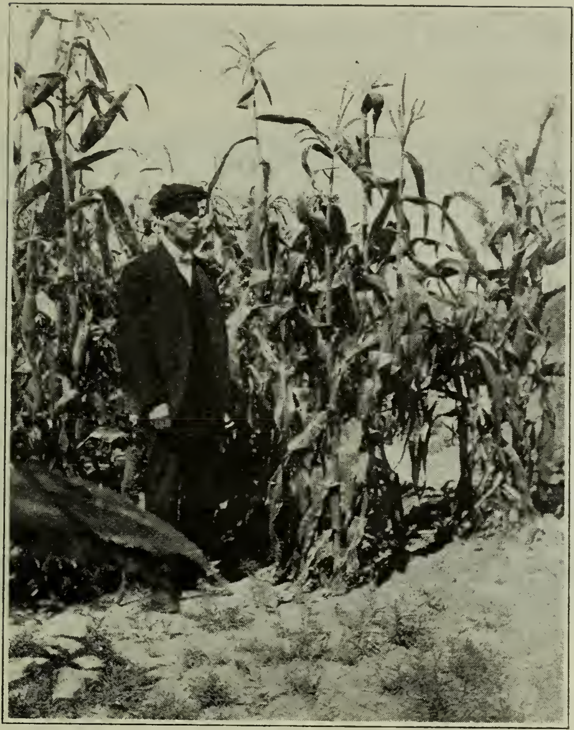


Fig. 24—Corn crop on Plot IV, August 1919. Note the small milkweed in foreground.

ches deep was dug along the full length of the patch on the side away from the ditch. This trench was then "moved across" the patch and all the roots thrown out, (Fig. 25).

On August 23, it was estimated that 3 per cent. of the milkweed was showing up, and the patch was thoroughly regrubbed. During the season of 1919, twelve spindling shoots of milkweed came up in the patch. The plot was covered with a heavy stand of horsemint which effectually shaded the ground and held the milkweed back. In this case over 99 per cent. of the milkweed was killed. **It is noticeable that in this case work was not begun unitl later in the season than on any previous plot, and that the ground was immediately taken by a plant that effectually shaded the soil.** It has been noticeable in all the eradication work for this plant that work begun early in the season is ineffective.

The closer it was to seeding time when work was begun the larger was the percentage of milkweed killed for the effort expended.

Plot VI. Late Summer and Fall Plowing.—This plot is located on the ranch of Mr. M. W. Milligan, 12 miles southwest of Cortez. Mr. Milligan did all the work under the direction of the Experiment Station. This plot was located in an abandoned field on red clay loam. On August 1 it was plowed thoroughly to a depth of 5 inches. On August 26, about 3 per cent. was showing through the surface, and a larger percentage was beginning to grow below the surface. The plants which were growing came either from stems that were not cut off or from solid ground below the furrow slice. The plot was again plowed September 2 to about 6 inches in depth and allowed to lie over winter. During the 1919 season about 10 per cent. of the milkweed came back. Practically all that came up was in the dead furrow where the roots were left exposed. The plot was thoroughly shaded with a stand of wild sunflowers, which seemed to hold the milkweed in check. Fig. 26 is a picture taken of the plot in late June, 1919. In 1918 this patch was solidly covered with milkweed. The shading of the sunflowers shown had much to do with keeping the milkweed in check.

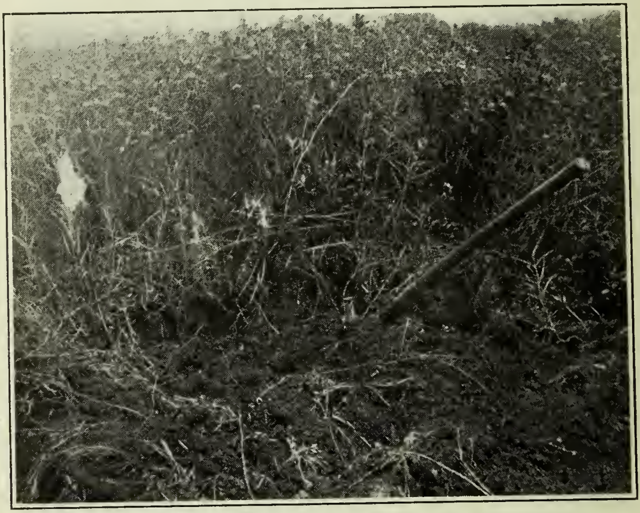


Fig. 25—Method of grubbing in small patches. Note bank to be worked to.

RESULTS OF WORK DONE BY FARMERS

All over the State where the milkweed exists, farmers have experienced a great deal of difficulty in making any headway toward eradication of the plant. The most common method tried by farm owners has been to cut the plant off a number of times during the summer season. In no case has any success been obtained by this method. One Japanese gardener near Delta, pulled or hoed the milkweed out of an onion patch ten times during the summer of 1918 and yet the stand seemed uninjured during 1919.

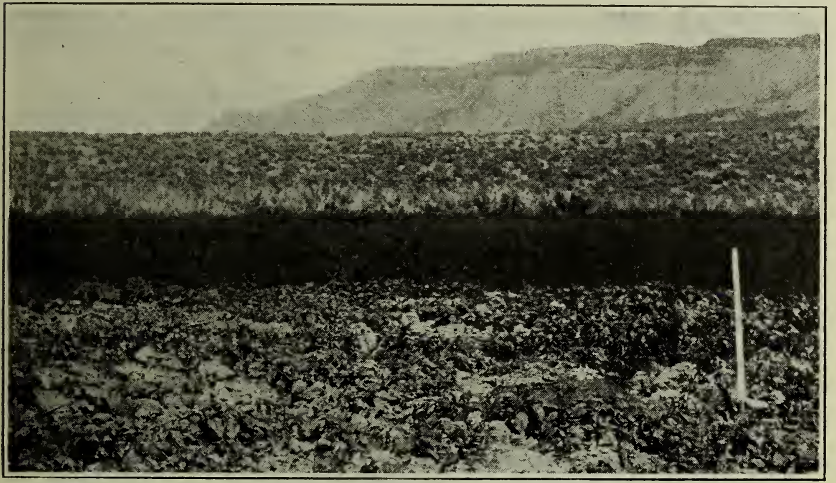


Fig. 26—Plot IV in June 1919. The heavy stand of sunflowers shaded and held in check the few milkweed plants that came back.

Some farmers are reporting good results from pulling the plant late in the summer when the ground is wet. Other reports are to the effect that this treatment does not kill any of the weed. In no case which has come under the writer's observation has this method given results that would warrant its recommendation as a means of eradication. In some cases the pulling has resulted in a thinning out of the stand and on wet, rocky hillsides, where the only object sought is to keep the plant from going to seed and to prevent poisoning while driving in the fall, this method is probably the best and cheapest to apply.

Under the direction of the Experiment Station, Mr. Robert Mead three miles east of Grand Junction, tried out a modification of the method followed in Plot VI, of the Montezuma Valley experimental plots, with very encouraging results. The field he worked on was the one previously mentioned, from which hay had been cut containing the milkweed that resulted in the poisoning of six head of horses. The field was plowed early in August to a depth of 4 to 5 inches, and allowed to lie until early in September, when it was plowed again and planted to winter wheat. The wheat got the start of the milkweed the following spring and the only place that the latter showed up was in the irrigation furrows. An examination of this field early in July, 1919, showed only about 10 per cent. as much milkweed as had been present the previous year. The crop of wheat, which had just been removed was excellent and the milkweed had been so checked by shading that the grain was cut above the top of the milkweed plants, consequently there was none of the poisonous plant in the straw. The field was again plowed in August, 1919, and in September, and again planted to wheat. Probably the best course to follow in this case would be to fallow again in 1920 after the removal of the grain and in 1921 to sow heavily to alfalfa, the object being to get in a crop as soon as possible that will completely take the ground.

ERADICATION ON ROCKY HILLSIDES

The most difficult problem from the eradication standpoint is presented by the occurrence of the whorled milkweed on the rocky hillsides below irrigation ditches. This condition is represented in Figure 27. The hillside shown is between Paonia and Hotchkiss in Delta County on a main stock driveway. This condition is prevalent for twelve or fourteen miles in this particular locality. The formation is as shown in Fig. 28. The ditch here shown is at

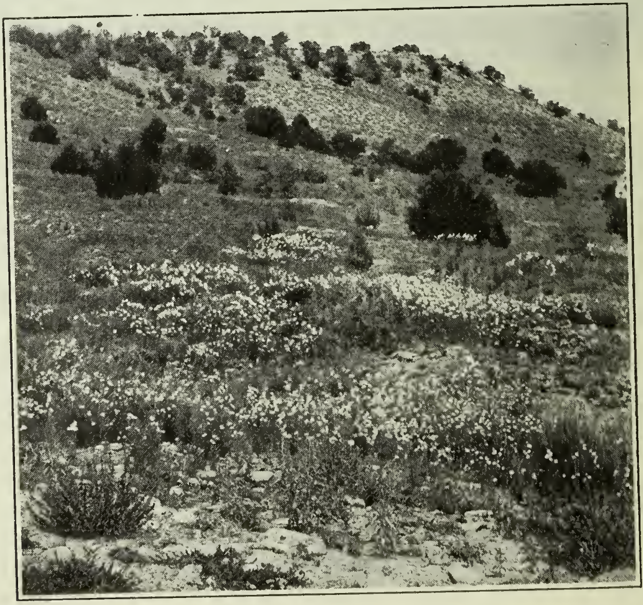


Fig. 27—Milkweed on hillside below ditch on driveway between Paonia and Hotchkiss.

the top of the hillside in Fig. 27. Water readily seeps out and keeps the hillside below rather moist beneath the surface.

A glance at the soil conditions here will show the impracticability of cultivation methods. The prevalence of this condition in certain sections of the Western Slope led to the beginning of a series of experiments using chemical sprays. So far these experiments have yielded only negative results, but it is contemplated that the work will be carried on another season.

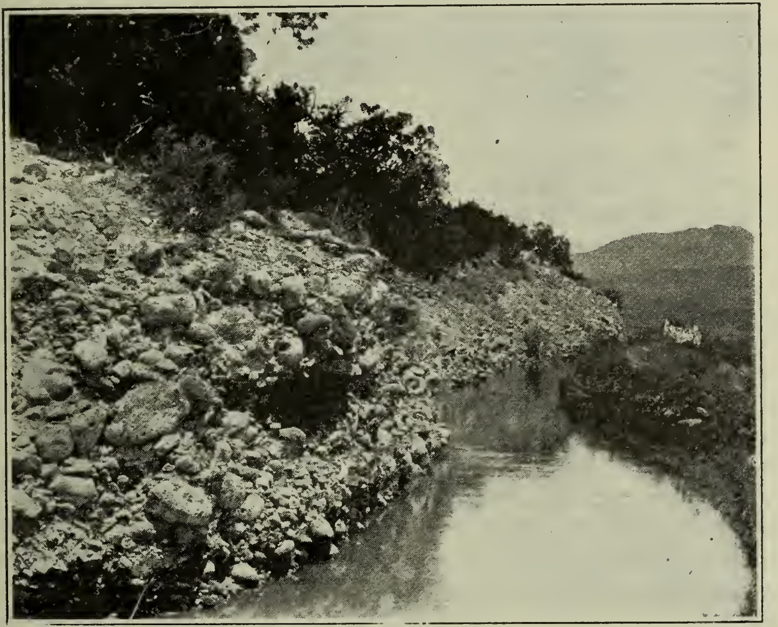


Fig. 28—The ditch above the hillside shown in Fig. 27. This gives an idea of the formation in which some of the milkweed occurs.

SUMMARY

1. Heavy losses of cattle, sheep, and horses on the Western Slope in Colorado have been due to *Asclepias galioides,* commonly called, in this State, the whorled milkweed.

2. This plant is pretty well distributed throughout the southern half of the State in irrigated sections from 5,000 to 7,000 feet in altitude.

3. Irrigation water, wind, railroads, and stock that are being moved are probably the most important factors in the spread of milkweed by seed.

4. Milkweed seeds are able to germinate as soon as they burst from the pod, and if kept under dry conditions, will retain their vitality unimpaired for at least a year.

5. Poisoning occurs under any condition in which hungry stock come in contact with the milkweed when there is a scarcity of other forage. This may occur (1) along driveways, (2) in overgrazed pastures, (3) in old orchards, (4) when milkweed occurs in the hay.

6. The only sure method of preventing poisoning is to keep hungry animals from coming in contact with the milkweed. As a beginning, the stock owner should first learn to recognize the poisonous milkweed.

7. The experimental work has demonstrated: (1) *Asclepias galioides* is not only a very dangerous poisonous plant, but it is one of the most persistent weeds that we have, ranking with bindweed and poverty weed in this respect. (2) Early summer work and surface work are equally ineffective. (3) Summer fallowing, followed by a hoed crop, was ineffective. (4) Three applications during a dry summer, of 10 pounds of salt in 5 gallons of water to a plot 10 feet in diameter did not kill the plant in 1918, but prevented its appearance in 1919. (5) The best time to begin eradication measures is as late as possible in the summer before the ripening of the seed. (6) For small patches, a grub hoe properly used is effective. The best method is to begin at one side and dig a trench and then "move the trench" across the patch. This first treatment should be just before seeding, usually early in August, and should be followed by another grubbing when green shoots appear in September. (7) For larger patches thorough plowing at the time given above for the grubbing has given good results. (8) In every case best results were obtained on plots where the grubbing or plowing was followed by a heavy smother crop. In Colorado, winter wheat is probably the best crop for this purpose.

ACKNOWLEDGMENTS

The writer wishes to express his thanks to the following persons who have aided him in the prosecution of the work on the whorled mlkweed problem: County Agents G. P. Newsom, E. D. Smith, H. C. Nevius, E. H. Divelbliss, L. P. McCann, B. H. King, and Waldo Kidder gave very material and helpful assistance in the field work. Claude C. Wakeland also rendered assistance in the field. To George E. Egginton, seed analyst of the Colorado Seed Laboratory, thanks is due for his careful work in making the germination tests reported in Table I. The suggestions Dr.W.W.Robbins thruout the work have been highly appreciated and have aided the writer materially. To J. G. Leach thanks is due for his painstaking criticism of the manuscript.

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Bulletin 256 August, 1920

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

HORTICULTURE AT HIGH ALTITUDES

By
R. A. McGINTY

1879

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

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INTRODUCTION

Much of the arable land of Colorado consists of mountain valleys and other areas which are located at what is commonly referred to as the "high altitudes". The growing season in such localities is short, and except for certain crops, is frequently unfavorable. Stock raising and potato growing under such conditions are often profitable, as the principles essential to success in these phases of agriculture are fairly well recognized. The same is not true, however, of some other phases, particularly horticulture. Gardening is done, it is true, in a more or less half-hearted manner, and occasionally even small home orchards are attempted, but information as to varieties and methods of culture, which is needed to make such ventures successful, has not been available.

With this in mind, it was decided by the Experiment Station authorities, in the spring of 1916, to begin some experiments in an attempt to secure information along this line. Accordingly, work was started both in agronomy and in horticulture. The writer was placed in charge of the horticulture work, and this bulletin is a report of the progress made to date.

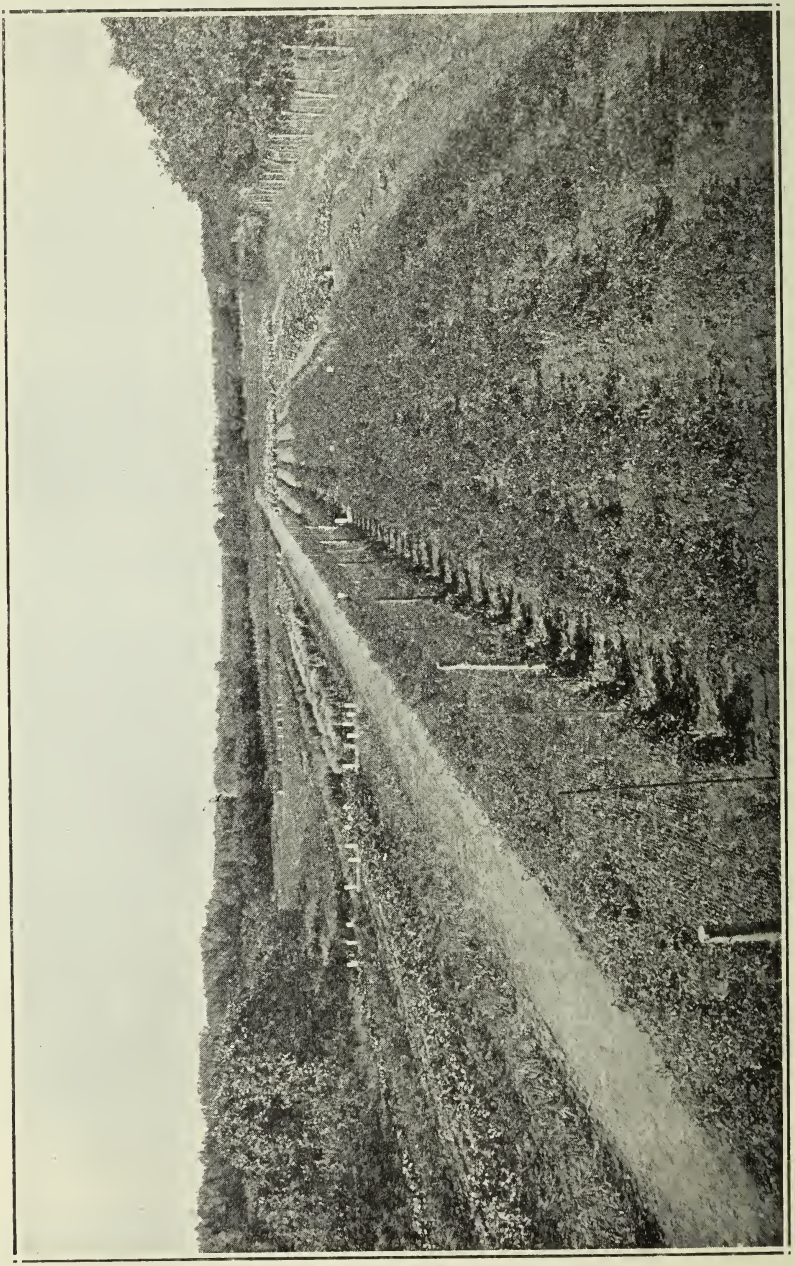
CONDITIONS UNDER WHICH EXPERIMENTS HAVE BEEN CONDUCTED

The Fort Lewis School of Agriculture, a branch of the State Agricultural College, was chosen as a convenient place for carrying on the experiments, because of its situation near the mountains and at an ***altitude of slightly more than 7600 feet. Frosts*** are expected there ***as late as June 10th*** and as early in the fall as ***Septembes 1st.*** Very light frosts may occur at any time, and the nights are almost invariably cold. The rainfall during the growing season is sometimes considerable. In the months of July and August, 1916, about 15 inches of rain fell. This condition, of course, makes less irrigation necessary, but tends to retard the maturity of certain crops. Heavy snowfall during the winter occurs quite commonly.

The land set aside for the horticultural work is located on a bench on an eastern hill-side, thus providing fairly good protection and air drainage. The soil is sandy and loamy in nature, and, while in a poor state of tilth in the beginning, is well adapted to the growing of vegetables and fruits. Water is available for irrigation at all times.

DIFFICULTIES ENCOUNTERED

Many difficulties have been encountered which have affected the results of the work considerably. The first year, due to a shortage of labor on the school farm, it became necessary to use inexperienced students in setting out a large number of plants,



View of Experimental Garden.

with the result that many plants died due to improper setting. For the same reason, the vegetable garden was not fall-plowed for the first two or three years. Spring plowing left the soil in poor physical condition, so that it was very difficult to secure good stands in the case of some vegetables.

Difficulty was also experienced in getting strawberry plants true to name, in getting true-to-name and disease-free seed potatoes, etc.

PLAN OF THE EXPERIMENTS

Work was planned and has been carried out along four different lines, as follows:

(1) ***An orchard*** of about 4½ acres was planted to apples, crab apples, plums and cherries with the idea of determining whether or not the hardier varieties may be expected to succeed under the conditions which prevail at Fort Lewis.

(2) ***A small fruit plantation*** about one acre in extent and containing a considerable number of varieties was planted in order to find which varieties are best adapted to high altitude conditions.

(3) ***The vegetable garden,*** which has varied in size from one to two acres, has been utilized in determining what kinds of vegetables may be grown under the conditions, and, of these kinds, what varieties seem best adapted to the higher altitudes. Incidentally the garden furnished a supply of vegetables for the school dining hall.

(4) ***A number of varieties of potatoes*** have been grown with a view to determining their behavior under the prevailing conditions. In this connection the hill selection method of saving seed has been followed.

THE ORCHARD

The orchard, consisting of about four and one-half acres, was planted in the spring of 1916. The planting comprised, originally, 13 varieties of apples, 5 varieties of crab apples, 10 varieties of plums and 5 varieties of sour cherries. Ten trees of each variety were planted in practically all cases. In replacing dead plum trees the second spring, trees of seven additional varieties of plums were used, three trees of each variety being set in the majority of cases.

It is too early yet to draw conclusions from the orchard work as the apple trees have not come into bearing, and a crop has not been obtained from the cherry and plum trees. A very few cherries and plums have matured but not enough to form any basis for conclusions. A few points in connection with the orchard work, however, may be of interest.

It is already evident that the greatest drawback in growing tree fruits, at the higher altitudes will be the prevalence of late spring frosts. These are very apt to occur when the trees are in bloom and destroy the crop for that season. Since fruit of any kind is usually at a premium in the mountainous localities, it may be advisable to plant a few trees of late blooming varieties even though two or three crops out of five are taken by late frosts.

Rabbits have been the source of considerable trouble. When deep snow covers the ground they are able to feed on the bark of the scaffold limbs of the trees, which are difficult to protect against attacks of this kind. A closely woven wire fence, 6 feet high to keep the rabbits out even in the case of deep snows, seemed to offer the best means of protecting the trees.

There are no indications that the trees themselves are not as hardy at Fort Lewis as elsewhere in Colorado. The bad effects of drying winds which frequently occur on the plains are not felt to the same extent at the higher altitudes, and winter temperatures are no lower. In seasons when considerable rain falls during July and August growth may be encouraged to continue too late in the season and make winter killing possible. The most trouble from this cause, however, is apt to occur when the trees are small and may not amount to anything after they reach bearing age.

As stated above a few fruits of the cherry and plum have matured, and the writer believes this is an indication that certain varieties of these fruits may be grown successfully at altitudes which have been considered too high for tree fruits. Further than this, nothing can be said at this time.

THE SMALL FRUIT PLANTATION

Strawberries.—In the spring of 1916 about one-third of an acre was set to ten varieties of Strawberries with the idea of testing them as to their adaptability. Unfortunately, the plants, when they bore fruit the next season, proved to be all of one variety and that not a particularly good one. Accordingly in 1918 new plants were ordered from a more reliable source, but they were in such poor condition when received that very few of them lived, and the work was again delayed. These are good examples of the difficulties which an experimenter is likely to meet with. Up to the present time no definite information as to varieties of Strawberries has been obtained. It may be said, however, that there seems to be no reason why strawberries should not succeed at the higher altitudes. They are by nature cool-loving plants and it is often possible for them to escape spring frosts which damage other fruits. If they are well mulched with straw in the fall, the mulch will aid not only in preventing the plants from bearing but will also retard the blooming season in the spring, thus helping to avoid damage by late frosts.

From the small amount of data at hand no definite recommendations can be made. The writer, however, would suggest the Senator Dunlap as a variety for planting until further information is available.

The everbearing strawberries seem to do well at high altitudes, and if it is desired to grow these, the Progressive and Superb are perhaps the best varieties. Spring planting is recommended, but fall planting (done the latter part of August) may succeed.

Raspberries.—Fifty plants each of the following varieties of raspberries were planted in 1916: Cuthbert, Loudon, Herbert, Marlboro, King, Miller's Red, Turner and St. Regis. A very small crop matured in 1917, but the 1918 and 1919 crops were killed by late frosts. A better knowledge of local conditions, however, would have made it possible to have avoided the injury in 1918.

Due to the fact that no crop of any consequence has so far been produced, definite recommendations can not be made at this time. Of the varieties planted, Cuthbert, Marlboro, and Loudon are well known and successfully grown in many parts of the State. St. Regis is one of the so-called "ever bearing" raspberries and appears to have some promise. It has a habit of bearing a crop in the summer and another in the fall. Herbert is a strong growing variety and produces large sized berries of good quality. It appears worthy of trial, especially for home use.

With raspberries, late spring frosts are also a considerable drawback. Damage from this cause, however, may be minimized by proper handling of the plants at time of uncovering. It is often difficult to know just the proper time to uncover the plants in the spring; therefore the following suggestions along this line taken from Bulletin 206, Colorado Agricultural Experiment Station, (Spur Blight of the Red Raspberry Caused by ***Sphaerella rubina,*** by Dr. W. G. Sackett) may be of interest here:

"Just when to take the berries up in the spring is always a problem, not because we do not know what practice is best to follow but because we do not know what weather conditions to expect. On the one hand, if the spring is going to be late, cold and dry, little harm will result if the canes are left buried until after the first of May; on the other hand, if it is warm and wet, nothing could be more disastrous than to allow them to remain covered until this late date. The danger from uncovering and taking them up too early results from subsequent late freezes during the first part of May. The fruit spurs are usually well advanced by this time, and the new canes are six to eight inches in height. If th bushes are left covered until late and the weather is warm, with considerable moisture, the canes throw out long, spindling white shoots which wilt and shrivel as soon as they come into contact with the air and sunshine, particularly if there is a little wind blowing; this, of course, means that the canes must grow a second set of fruit spurs, which, at their best are inferior to the first. While there is some difference of opinion concerning the wisdom of early or late uncovering, the most successful growers are agreed that the former procedure is the safer practice.

"The method adopted consists in plowing away the soil from the sides of the row early in April, and in gradually removing the soil from the top so as to admit air and sunshine. In this way, the young growth becomes accustomed to the new conditions gradually, and is hardened off before it is completely exposed; at the same time, the canes have an opportunity to dry off, and if severe cold weather does follow, they will be in a more resistant condition that if saturated with water. The canes may be left in this semi-covered condition for eight to ten days, or even longer, if cold weather prevails, without doing them any injury. With this preliminary hardening, they should be ready to take up by the middle of April, and should be able to withstand rather wide ranges of temperature."

We would recommend that raspberries be planted in the spring. The land should be well fertilized and in good condition before planting, as the crop occupies the space for several years. The plants should be set about four feet apart in the row, with six feet between rows. Cut out all canes which bear fruit, as soon as the latter is harvested. Cover the plants about the first of November, uncovering them, as suggested above, in the spring.

Gooseberries and Currants.—These fruits deserve an important place in high altitude horticulture because of their hardiness and adaptability to conditions. They are rarely injured by the cold of winter, and escape late spring frosts which kill other fruits. They usually bring good prices when sold.

We have been rather unfortunate with these fruits for the reason that we were unable, on account of lack of funds, shortage of space, labor, etc., to devote but a small area to them. Only ten plants of several varieties were planted and these were so badly started when received that a majority of them died after planting.

The following varieties were planted: ***Currants:*** North Star, Cheney, Red Cross, Fay, Red Dutch, Pomona; ***Gooseberries:*** Industry, Keepsake, Red Jacket, Houghton, Joselyn, Downing and Smith's Improved. Most of these varieties are well known and from the limited observations made, seem to do well.

If one wishes to plant only a variety or two of each we would suggest the following: Currants: Fay or Red Cross; Gooseberries: Downing, Joselyn, Industry.

Planting should be done as early in the spring as possible, otherwise the buds are apt to be badly started making the plants more susceptible to injury from transplanting. This is especially true if plants are shipped in from lower altitudes where the season is somewhat earlier. Plants should be set about the same distance apart as recommended for raspberries, that is, four by six feet.

THE VEGETABLE GARDEN

More conclusive results have been obtained with vegetables than in any other phase of the work. Successful crops have been planted and grown for four years and it has been demonstrated that most of the common vegetables will succeed under conditions which obtain at Fort Lewis. In the following paragraphs are taken up the various points which seem to be of most importance in this connection.

Location of Garden.—The high altitude vegetable garden should be located in the most protected place possible. A southern or eastern slope is preferable, and if there are buildings, trees or other protection on the north and west sides, the location will be all the more desirable. A sandy loam soil is best, but other types may be made to produce good vegetables.

Preparation of Soil.—The garden should, by all means, be plowed in the fall. This insures that the ground will be in the best physical condition in the spring and makes earlier planting possible. The land should be left rough over winter and then harrowed down when ready to plant. A good application of stable manure should be put on before plowing in the fall.

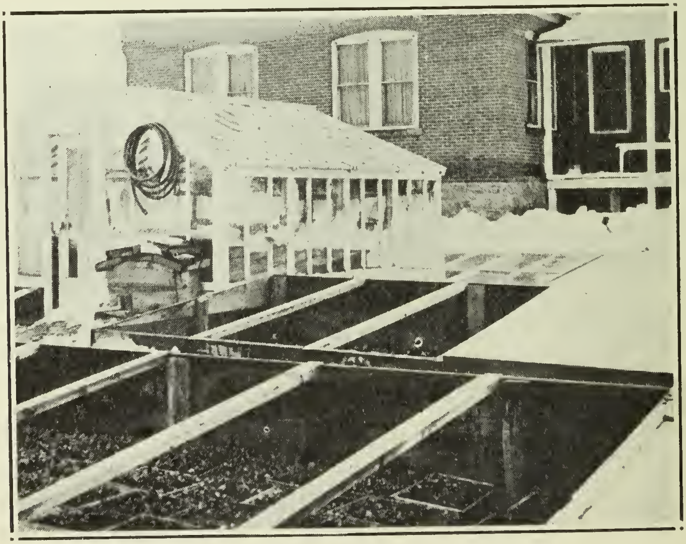
Seed.—The gardener who grows vegetables at high altitudes should be careful as to the seed he plants. Only certain varieties of some vegetables (tomatoes for example) will succeed, and care should be taken to secure only those varieties which are sure to make a crop. Seed should be bought locally, or ordered from a reliable seedsman, early in the year so as to be sure of getting the desired varieties and having them on hand when planting time arrives.

Irrigating the Garden.—Vegetables can not be expected to reach perfection unless they have an abundance of water. In applying water, it is well to remember that good soakings are preferable to light waterings. The garden should be irrigated whenever the plants need water. A small stream, running for several hours, is preferable to a large one which is allowed to run only a short time. When the indications are that it may be necessary to irrigate in order to get seeds to come up, furrows for this should be made at planting time so as to be sure of getting them in the right place.

Cultivation.—Cultivation in the garden should be frequent and shallow. Root crops may be cultivated rather deeply in the early stages, but in general, cultivation should not be more than two or three inches deep. Irrigation furrows, as soon as they have dried out sufficiently, should be cultivated up to check evaporation from the soil. Cultivation should not be done when the ground is too wet as it leaves the soil in bad physical condition.

Hotbeds.—The gardener is often unable to get plants of the kind he desires locally, and must take undesirable plants or grow them himself. The latter procedure is best as one is then sure of having a supply of plants of the desired varieties. These may be grown in boxes of soil placed in a south window of the kitchen or living room, but a small hotbed of two or three sash is a much more desirable place to grow such plants. In such a structure the plants have more nearly the conditions they need and more of them can be grown.

Full information as to the making of hotbeds and cold frames and their uses may be had by addressing the Colorado Agricultural Experiment Station, Fort Collins.



Small greenhouse and hotbeds at Fort Lewis. Note plants growing in flats in hotbed.

Asparagus and Rhubarb.—These perennial vegetables should be found in every garden. They are hardy, free from insects and diseases and are desirable additions to the vegetable diet. Once planted, they will produce crops for years if given a fair amount of cultivation and fertilization. Neither of these vegetables was included in the experimental plantings because there were plantings already established when the work was begun in 1916. These served to show that asparagus and rhubarb grow well at high altitudes. Any of the cultivated varieties may be grown.

Beans.—This vegetable is commonly considered a tender crop, requiring warm weather for best development, and it might therefore not be expected to succeed where cool days and cold nights prevail. As a matter of fact, however, snap beans do well. They will sometimes undergo light freezes without being damaged, a fact which often makes it desirable to take a chance and plant before all danger of frost is past. If such planting succeeds, an early crop results, while if the beans are killed by a hard frost only the seed and labor of planting are lost.

A number of varieties have been grown but Stringless Greenpod is the most desirable. Bountiful, another green podded kind, also gave good results. Of the wax-podded varieties tried, German Black wax is perhaps the best. These varieties will all produce edible pods in 60 to 75 days from planting. Though not thoroughly tried out, it seems that mature beans of the Pinto type may also be grown, if planted as early as possible. Limas have not proved a success.

Cabbage, Cauliflower and Brussels Sprouts.—All members of the cabbage family of plants grow to perfection at the higher altitudes where the cool seasons are especially favorable for their development. Any varieties will grow well but the following are some of the more desirable kinds:

Early Jersey Wakefield produces small conical- shaped heads which are the earliest to mature. Copenhagen Market is a very desirable early maturing variety. The heads are large and round. Danish Ballhead produces hard round heads of good size and should be grown for winter storage. American Drumhead Savoy is a variety of extra good quality. It has crumpled leaves.

Earliest Snowstorm, Early Snowball, Dwarf Erfurt and Dry Weather are good varieties of Cauliflower. This vegetable may be grown to perfection when carefully handled. The plants should not become checked at any stage in their growth as they will not develop properly afterward.

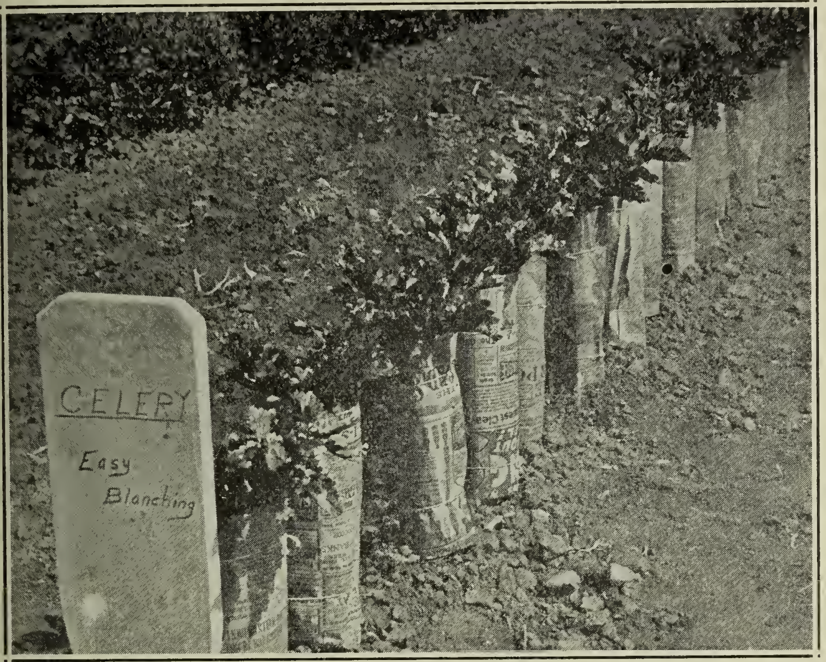
Trimmed heads of cabbage are Copenhagen Market; Cauliflower is Snowball. These vegetables grow to perfection at high altitudes. Note Savoy Cabbage in center.

Brussels Sprouts is a member of this group which is not cultivoted as much as it should be. They demand the same treatment as cabbage but require a longer time for development. One drawback in growing Brussels Sprouts is the fact that the plants are attacked by plant lice which, if numerous, make the sprouts unfit for use. They may be controled by spraying with kerosene emulsion when the insects first attack the plants.

All the vegetables in this group may be started indoors about March 1st to 15th, though six weeks later is soon enough for late cabbage which is to be stored for winter use. Transplanting outdoors should be done in May. Cabbage and related plants are quite hardy and will endure considerable frost.

Celery.—Celery of the highest quality may be grown under conditions such as prevail at Fort Lewis. Golden Self Blanching and Giant Pascal have both been grown with success. Seeds should be planted about April first and the plants set in the garden the middle or latter part of May. Golden Self Blanching is ready for use in September or earlier, and Giant Pascal is a good sort for winter storage.

Lettuce.—Out on the plains, it is difficult to grow good lettuce, except as an early spring crop and head lettuce sometimes



A good way to blanch the easy blanching varieties of celery. The green varieties such as Giant Pascal should be blanched with soil.

fails to succeed even then. At the higher altitudes, however, both leaf and head lettuce do exceptionally well whether grown as a spring or summer crop. Those who prefer head lettuce need grow no other. The plants are hardy and seed may be sown outdoors the first of May. Lettuce is a good hotbed crop and where hotbed space is available some should be grown for early use. The seed may be planted in the hotbed the latter part of March.

Grand Rapids is the best variety of leaf lettuce. Among head lettuces, Wayahead is one of the earliest and best. New York, or Wonderful, forms very large solid heads of good quality. Deacon and Deer's All-Heart have also proven to be good.

In growing head lettuce, it should be remembered that the plants must have room to develop properly. This means that when they have formed the second pair of leaves, they should be thinned to stand about six or eight inches apart in the row.

Melons, Squashes, Pumpkins and Cucumbers.—These vegetables are grouped together because their requirements and methods of culture are similar. They are quite susceptible to frost and outdoor planting can not be done until danger of frost is past. Cucumbers and Summer Squashes will mature when seed is sown out-

One picking of Cucumbers. On the right are Melon vines; Celery on the left.

doors about the first week in June. But the others should be started in a hotbed the latter part of April and transplanted to the field about the 15th of June. This group of plants will not endure having their roots disturbed so they must be started in paper or clay pots, dirt bands, or on squares of inverted sod. Four or five seeds should be planted in each pot and when these have come up, all but the two best are thinned out. When ready to set in the field the whole mass of soil around the roots is planted so as to leave the root system intact. If clay pots are used the mass of soil containing the plants may simply be knocked out of the pot and set in its proper place. If paper pots or dirt bands are used these should be torn away when the plants are set out. This method of handling these crops lengthens the growing season for them considerably and gives them a better chance to mature.

By starting the plants as described above we had very good success with Emerald Gem and Montreal Market Muskmelons, Hubbard Squash, and Small Sugar or pie pumpkins. Early White Bush and Golden Crookneck Squashes (both summer varieties) also did well.

Several varieties of cucumbers have been grown, of which the following are desirable: Davis Perfect, Everbearing, Cool and Crisp and White Spine.

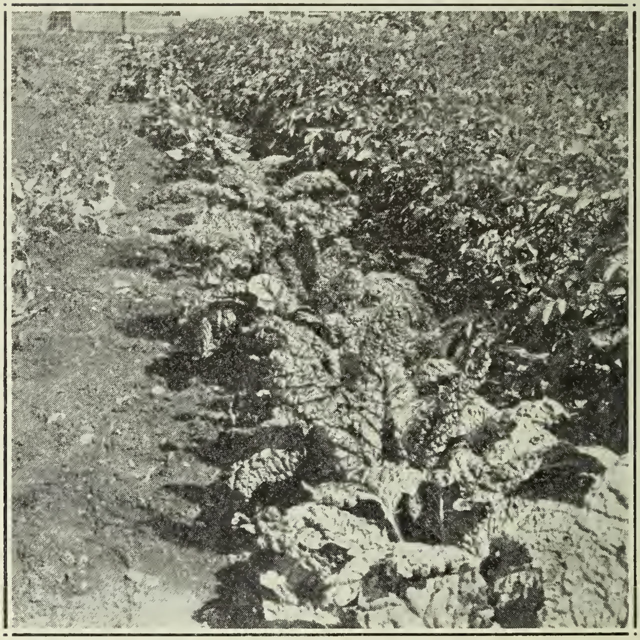
White Bush, or Scalloped Squash. An early prolific summer variety.

Cucumbers may be planted out doors after danger of frost but better results will be had if they are started in a hotbed.

Onions.—It has been found difficult to grow good onions from seed at Fort Lewis. One reason for this is that circumstances have made late planting unavoidable. This vegetable is hardy and should be planted as early as the ground can be put in condition. By using early varieties, such as Extra Early Red or White Silverskin, and planting early, it should be possible to grow good mature onions from seed. Mature onions may be grown from sets planted early in the spring, though a considerable per cent of the sets will go to seed instead of producing large bulbs.

Peas.—Good success has been had with peas, as they are naturally a cool season crop. The vines continue to bear for a longer time than is the case in warmer localities where they often die after a short period of bearing.

A number of varieties of peas have been grown and most of them have done well. Alaska is one of the earliest varieties and is dsirable because of that and also because it may be planted quite early. Its quality, however, is not so good as later varieties. Market Surprise and Gradus are somewhat later than Alaska but better in quality and are desirable varieties to grow. Thomas Laxton, Telephone and Sutton's New Discovery are other varieties which have given good results.



Swiss chard or leaf beet. A desirable plant for greens.

Root Crops.—Under this heading may be considered carrots, parsnips, beets, turnips and radishes. All of these are hardy and seeds may be sown early in the spring. It is better, in fact, to plant them early in order that better stands may be secured. If planting is delayed so that irrigation is necessary to get the seeds to germinate, poor stands frequently result. All of these vegetables grow to good advantage at the higher altitudes, and while any varieties will, as a rule, do well, some are better than others.

Chantenay, Coreless and Danver's Half Long Orange have been found to be good varieties of carrots, while among the parsnips, Guernsey and Hollow Crown have proved worthy of recommendation.

Of several varieties of beets tried, Dark Stinson and Detroit Dark Red have given the earliest roots of edible size. The quality of these varieties is good. Later maturing varieties of beets which are worthy of a trial are Black Red Ball and Improved Blood Turnip.

Red Top White Globe is the best turnip we have tried. It produces large roots of good quality and flavor. Purple Top Milan is a smaller, earlier variety, but the quality is not so good. White Fleshed Neckless, Breadstone and Imperial Hardy are varieties of rutabagas which have succeeded. Some of these should always be grown for winter storage.

Any varieties of radishes grow well. Rapid Red is one of the quickest maturing. Other desirable but somewhat later varieties are Vick's Scarlet Globe, French Breakfast, White Olive Shaped and White Icicle.

Sweet Corn.—A number of varieties of sweet corn have been tried out, but Golden Bantam is the best of them all. It is one of the earliest and is of good quality. Extra Early Adams is an early, large-eared variety but cannot compare, as far as quality is concerned, with Golden Bantam.

It frequently pays to take a chance with sweet corn and plant it before all danger of frost is past. If the plants escape, valuable time is gained, while if they are caught by late frosts, the loss is small. It is not worth while to try to grow the late maturing varieties such as Country Gentleman and Stowell's Evergreen as the season is too short for them. Only the earliest varieties should be grown.

Tomatoes and Peppers.—The tomato is always a desirable vegetable, but at high altitudes it is usually scarce and high in price. It requires some care to grow tomatoes under these conditions and one is apt to consider it a more or less hopeless task. However, this is not the case. We have grown and ripened quan-

TOMATO
Earliana

Tomato Plat. Good tomatoes may be grown by selecting early varieties and handling properly. Training to stakes gives somewhat earlier results.

tities of tomatoes at Fort Lewis with little trouble. Success with this crop depends upon the ***selection of early varieties*** and ***proper handling.*** The warmest, sunniest location in the garden should be chosen for planting to tomatoes, and the soil should not be too rich. The plants should not be over irrigated, but given just enough water to keep them growing.

Seed should be sown about April 1st, and a hotbed is very desirable for this purpose, although plants may be grown in the window of the living room or kitchen. Planting earlier than the first of April is not recommended as the plants become stunted before time to put them in the fields. Small boxes of soil make convenient places for planting the seed. When the plants have formed the second pair of leaves they should be transplanted into other boxes of soil, giving them about two inches apart each way. As the plants should be well developed and of good size when planted outdoors, they ought to be given still another transplanting when they have begun to crowd. If six-inch paper or clay pots can be used for this, better results will be obtained as the plants will then not have their roots disturbed when set outdoors. These pots may be secured from the nearest florist or may be ordered from seed houses. Since the home garden does not require a large number of plants this is not an expensive item. Clay pots may be used for years, but the less expensive paper ones will last only one season.

The plants should be grown with as little check as possible until about June 15th when they should be planted in their permanent places in the garden. If transplanted without disturbing the root system, the plant will grow off without a check. Four feet apart each way is about the right distance to set the plants.

If the points mentioned above are observed success will follow. There seems to be a slight advantage in the matter of earliness, in training the plants to a ***single stem.*** This is accomplished by pinching out lateral branches when just starting. The single-stemed plant so obtained should be tied to a stake to hold it up, as it will reach a height of four to six feet, before the season is over. It may be stopped at any desired height by pinching out the tip.

Only the earliest varieties of tomatoes should be tried. Spark's Earliana has always given us the earliest fruits, though some others are just about as early. Of these the following have proven most desirable: I. X. L., Prosperity, King of the Earlies, Burbank, Earliest of All. Chalk's Early Jewel and John Baer, both much grown in Colorado, have not succeeded at Fort Lewis.

We have been able to grow the large bell peppers with less trouble than tomatoes. The plants may be handled the same as tomatoes, except that it is not necessary to transplant into pots

Ruby King and Early Neopolitan are suggested as varieties which may be tried.

Vegetables for Greens.—Spinach is the most important plant grown for greens. Being very hardy, the seed may be sown as early as the ground can be worked in the spring. Long Season and Victoria are both desirable varieties.

Swiss Chard is a leaf beet which makes good greens. It should be planted after the middle of May. Beet thinnings are also excellent for this purpose.

Pe-Tsai or Chinese Cabbage is another desirable vegetable which may be put in this class. When well grown, it forms large, long, solid heads which are very palatable. It is a member of the mustard family and should be planted early.

Kale is a loose leaf cabbage which is desirable for use as greens late in the fall. Its quality is improved by a certain amount of frost. Dwarf Curled Scotch is a good variety.

POTATOES

The culture of this important crop is well understood and it is hardly worth while to go into the details of cultural methods here. Bulletins on the subject are available and may be secured from the Director of the Experiment Station at Fort Collins. A few words, however, as to the work done at Fort Lewis may not be amiss.

The following varieties have been grown: Irish Cobbler, Bliss Triumph, Rural New Yorker, Brown Beauty, Russett Burbank, Pearl and Peach Blow.

Much difficulty has been experienced in obtaining good seed potatoes and considerable effort spent in attempting to purify the varieties. The hill selection method of saving seed has been followed and considerable progress has been made in bettering the strains.

It has not been feasible to determine comparative yields except in a general way. Rural New Yorker has proven to be the heaviest yielder so far, although all varieties may be expected to do well. Bliss Triumph is a good early variety, as is also Irish Cobbler. Brown Beauty has a good record for heavy yields and should succeed. It is hoped that more information along this line may be available at some future time.

ACKNOWLEDGEMENTS

The writer wishes to thank Dr. E. P. Sandsten, Head of the Department of Horticulture, Colorado Agricultural College, for his hearty support of this work and for his valuable advice in many instances. Thanks are also due the Fort Lewis School for aiding as far as possible in carrying on the work.

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Bulletin 257 June, 1920

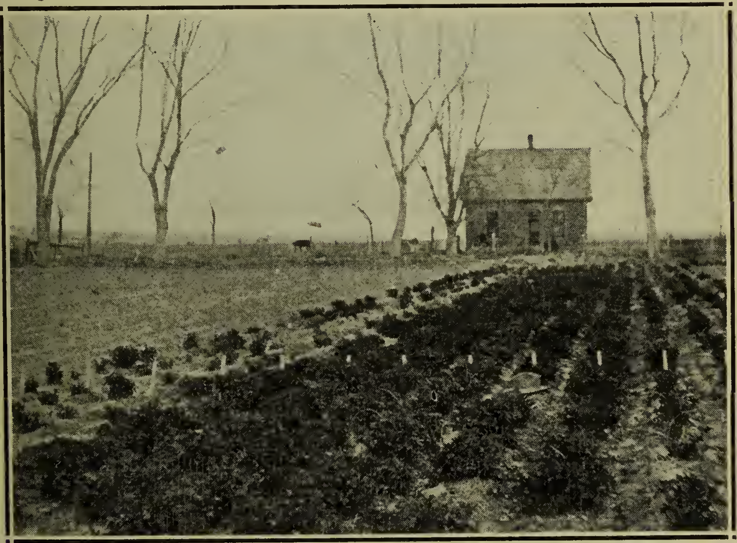
The Agricultural Experiment Station

OF THE

Colorado Agricultural College

FACTORS THAT AFFECT ALFALFA SEED YIELDS

By PHILO K. BLINN



The first alfalfa nursery test. Seed was sown in 1905. The six center rows are Turkestan alfalfa. The four rows at either side are common alfalfa.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

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Factors that Affect Alfalfa Seed Yields

A Progress Report

By PHILO K. BLINN

The problem of alfalfa seed production is a vital one to the armers in Colorado. Alfalfa occupies the same important place in he farm economy of the West that red clover occupies for the farms n the East. Alfalfa has even greater importance, due to its larger orage producing capacity and its very great power as a fertility builder on western soils. Due to its fertilizing value, it plays an important role in western crop rotation.

Immense quantities of alfalfa seed are required each year to reeed new acreages, resulting from crop rotation. The production of alfalfa seed does not seem to be keeping pace with this ever increasing demand. The inability of seed production to keep pace with seed demands seems to be largely due to the uncertainty of alfalfa seed yields. With uncertain seed yields, there is not strong encouragement for farmers to attempt to produce alfalfa seed. Recently, it has seemed that alfalfa seed could be successfully produced only under the most favorable circumstances. Even then seed yields are so irregular from season to season that the irregularity constitutes a strong business limitation on alfalfa seed producing efforts.

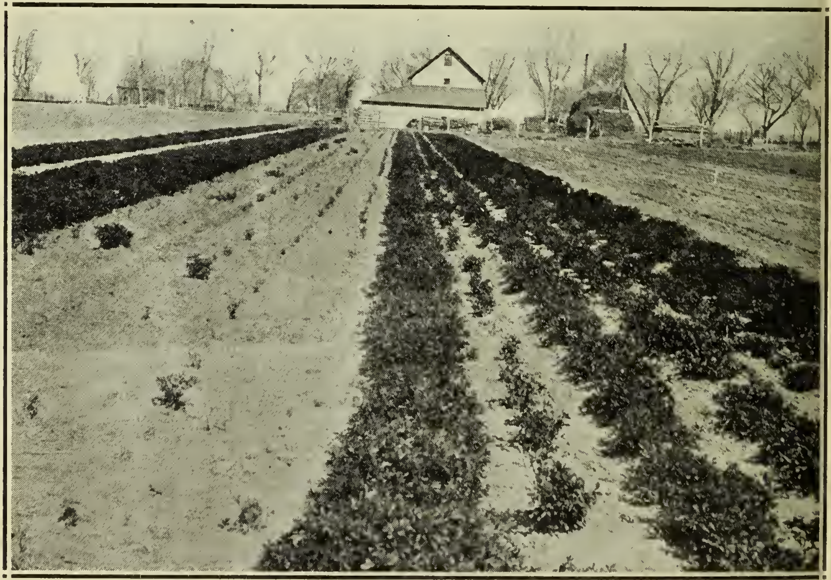
For a number of years the Colorado Experiment Station has been endeavoring to determine the causes of uncertain alfalfa seed yields. The Experiment Station has tried to find the controlling factors in seed yield. It has tried to work out the cultural methods necessary to insure successful alfalfa seed production. These efforts have been put forth in the hope of developing a seed growing industry which would at least supply the demands of Colorado growers for good alfalfa seed. Investigations cover a period of over twelve years. It seems advisable at the present time to publish the results of these experiments and observations. The final conclusions, however, seem somewhat indefinite. A clear-cut statement of the status of the investigation may serve to clarify the problem and offer some beneficial suggestions to those engaged in producing alfalfa seed. It is hoped the results will be helpful, even though they do not give a final solution to the problem.

Investigations have been conducted chiefly on the Colorado Experiment Station farm at Rocky Ford. This farm has excellent land

and dependable water rights. It is located in one of the largest alfalfa growing districts in the state. At one time the Arkansas Valley was a very important alfalfa seed producing region. The experiments at Rocky Ford have been supplemented by co-operative tests with alfalfa seed growers in different parts of the state. Much work has been done in collaboration with the Office of Forage Crop Investigation, Bureau of Plant Industry, Washington, D. C. The field observations have covered Colorado and a portion of the alfalfa seed producing sections of Utah and Idaho. The Office of Forage Crop Investigation has furnished several lots of alfalfa seed varieties from different parts of the world which have been used in the tests and experiments.

In the preliminary canvass of the investigation, theories and beliefs were advanced by different growers and others in an attempt to explain the causes for success or failure of alfalfa to set seed. The concensus of opinion seems to be that the care of the crop, together with the ability of the grower to judge of the prevailing conditions and their effects upon the seed production are the most important factors.

A careful comparison of the results secured under actual field conditions seemed to be the most plausible method of attacking the problem. Accordingly, tests have been made and observations



A later alfalfa nursery test of different types and varieties. Notice the large stooling row in the center, a typical hardy strain. The winter killed rows at the left and one on the right of the hardy strain came from Italian strains of seed, all of which are non-hardy.

Abnormal root development of hardy plants grown from cuttings.

carried out with practical growers, in addition to the carefully planned work on the Experiment Station grounds.

In describing the progress of these investigations, it seemed best to present the matter under the topical heads which might be considered the principal factors apparently influencing alfalfa seed yields. No attempt has been made to arrange these topical heads in the order of importance because their relative importance has not been determined by the experiment.

SEED SETTING TENDENCY OF DIFFERENT VARIETIES

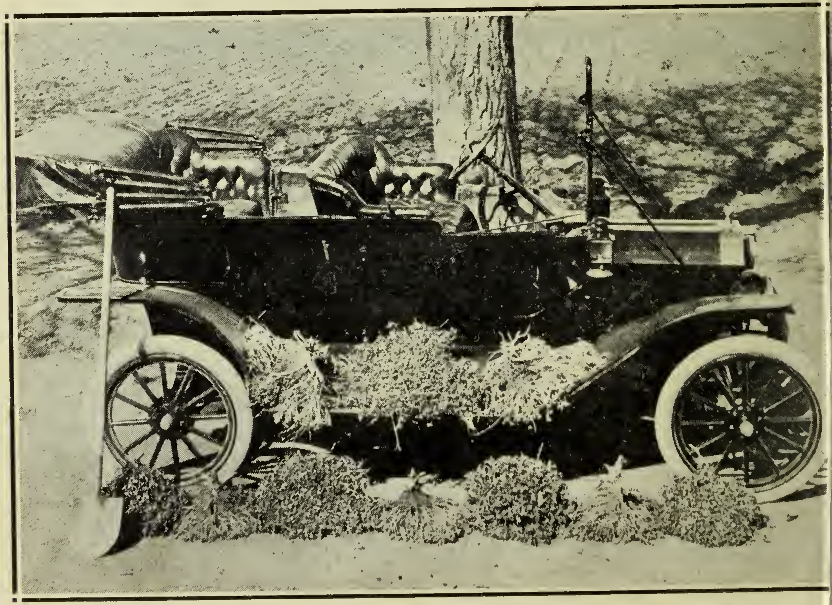
It is noticeable in every field of alfalfa left for seed that there is a great range of difference in the seed yields of different plants. This characteristic is apparent, even when all of the plants are growing under as nearly similar conditions as it is possible to impose. This fact, observed as early as 1904, led to the selection of a number of heavily seeded plants of common alfalfa, with a view of testing out plants with strong seed yielding tendencies in the hopes of developing an improved strain of alfalfa with strong seed producing power.

The first selections were sown in the spring of 1905. At the same time there were put out tests of imported Turkestan alfalfa seed.

The plantings were made in adjacent plots, the condition of the two being as nearly uniform as possible. A few more selections were added in 1906. It so happened that the Turkestan strain proved to be so superior to the common alfalfa in both forage development and seed production that it was evident that a larger test of varieties would be desirable in order to get the best type from which selections might be made. These first selections were finally abandoned and a much larger test was started in the spring of 1907. The enlarged test comprised sixteen choice selections from heavily seeded Turkestan rows. It contained, in addition, 48 regional varieties of alfalfa from different parts of the world, furnished to us by the Office of Forage Crop Investigation, United States Department of Agriculture. This list of varieties included alfalfas from northern and southern climates, from both eastern and western hemispheres.

Each variety consisted of two square rods, sown in hills spaced twenty inches apart each way. Each hill was thinned to a single plant. The entire nursery was given, as nearly as possible, the same culture and irrigation. During the season of 1908, the whole nursery was left to produce seed.

The contrasts in results of both seed yields and forage production were very marked. The extreme southern strains of seed, such



A group of hardy plants of the extremely large crowned type. This type is extremely hardy. But, owing to its excessive stooling habit, it is undesirable for either hay or seed production in our climate.

Extra large crowns of alfalfa developed from a single seed as they appear growing in the field. These are very hardy. But, owing to their low growth, are undesirable for hay production. These types are also poor seed producers.

as those from Ecuador, Peru and Tripoli, gave evidence of having the strongest inherent seed setting tendency. These strains exhibited a small stooling, tall growing type of plant, apparently not the most desirable type for hay production. The northern grown strains of alfalfa had a heavy stooling type of crown. They produced a much branched, fine stemmed plant, which seemed well adapted for hay production. In general, the northern strains were deficient in seed production. The common strains of alfalfa from Colorado, Kansas and Utah were intermediate in type between the northern and southern strains. The seed yields and forage production were also seemingly intermediate between the northern and southern extremes. There were some plants in the common strains that seemed similar to the northern strains, while other plants seemed more like the southern varieties. There were plants which seemed to combine some of the traits of both northern and southern types. It has often seemed that good seed yields and heavy forage production were antagonistic traits. Yet numerous instances occurred where plants were found which seemed to combine these two desirable qualities in the same plant. Such plants were found in several of the best commercial strains, such as the Grimm and Baltic.

SEED SELECTION TO IMPROVE SEED YIELD

It seemed possible to produce a strain having the ability to produce a good yield of hay and at the same time a good yield of seed.

With this object in view, a number of individual plant selections were made.

After the variety test had passed the second winter, it became very evident that there were non-hardy strains of alfalfa in the test. This was evidenced by heavy winter killing in certain of the plants. The proportion of loss seemed to be correlated with the region from which the variety came. The extreme southern varieties were almost completely winter killed. The extreme northern varieties practically escaped winter loss. Further investigations revealed a relationship between the type of plant and its ability to withstand winter injury.

It was found that the plants with an **upright growing type of crown,** where the stems started out near the surface of the ground, were the plants which suffered most from winter killing. In this type of crown, the buds for the next season's growth were more or less exposed to freezing and thawing and drying out. At any rate, the type of plants with the exposed crown suffered winter losses much more extensively than the type having a more deeply submerged crown.

On the other hand, the alfalfa plants which had a **heavy stooling habit** with a **spreading crown,** the buds of which largely started beneath the surface of the soil, suffered much less from winter killing. Evidently there is a difference in plant resistance in these two types of alfalfa. But the fact that the buds of the erect type are more exposed to freezing and thawing than the buds of the heavy stooling type may have something to do with winter resistance. The northern or heavy stooling types have their buds protected by a considerable layer of soil. Hence, freezing and thawing and drying out are reduced in effect. It is probable, therefore, that a part of the hardiness is due to inherited qualities and a part to protection, due to the habit of growth.

The conclusions of these observations were published in 1911 in the Colorado Experiment Station bulletin No. 184, "Alfalfa, The Relation of Type to Hardiness."

It thus became evident that any system of seed selection to improve alfalfa must take into consideration the question of hardiness and desirable forage production, as well as good seed production. With this in view, a long series of individual plant selections of special merit have been made during the past ten years.

Over 400 specially good plants have been saved separately and tested for comparative values. Their progenies have been reselected for several generations, where the results seemed to warrant.

SUMMARY OF COMPARATIVE TESTS

The results of these comparative tests, together with the individual plant selections, might be summarized in the following statements:

1. The **northern strains** of alfalfa have proven to be the most desirable for forage production. They are poorest in seed yields. The **southern strains** were best in seed production. The southern strains winter killed so badly as to be impractical.

2. The **Baltic and Grimm strains** of alfalfa have proven to be most desirable for Colorado conditions. In hay production, they have been about equal in all of our tests. The Grimm alfalfa is thought to be a little more hardy and is somewhat heavier stooling. It is thus finer stemmed. The Baltic has proven to be less susceptible to the bacterial stem blight than other strains of alfalfa. The Baltic has been somewhat better in seed yield than the Grimm. These two strains resemble each other so closely that there is little choice between them.

3. The selection of plants for **high seed yield** has resulted in locating some phenomenally high yielding plants. Selection has produced some specially large stooling crowns. But the high seed yields and large crowns did not occur upon the same plants or strains.

4. The selection of **desirable forage types** has improved uniformity in some strains. This improvement has been sufficient to produce a better quality of hay, while at the same time increasing

A view of the alfalfa nursery, showing the variation in types of plants from different seed sources.

A different view of an alfalfa nursery, showing the variation in the development of alfalfa plants. The small plats are grown from seed from an individual source. Differences can be seen in the progenies, as each plat represents a progeny.

hay yields to a certain extent. But the largest crowns did not produce the highest yields. Crowns were found that would occupy over four square feet of ground. Such crowns were developed from a single seed. These extra large crowns produce enormous numbers of stems. But the stems are usually fine and short. Consequently, the large crowns do not usually make maximum hay yields.

5. The selections for high seed yields located a number of plants that produce as high as eight ounces of clean seed per plant. But the progenies grown from these high seed yielding plants in the subsequent generations have not produced uniformly high seed yielding plants. There is some evidence of a slightly better seed setting tendency. But it seems apparent that the heavy seed yields which are often found with individual plants are not entirely due to strong inherent seed setting qualities. Evidently there are other factors, local or inherent, which favor or retard the setting of seed. Hence, seed selection alone does not seem an adequate solution of the problem.

IRRIGATION AND MOISTURE REQUIREMENTS FOR ALFALFA SEED YIELDS

The proper amount of soil moisture required for the best yields of alfalfa seed has long been regarded as one of the first essential conditions for the successful production of alfalfa seed.

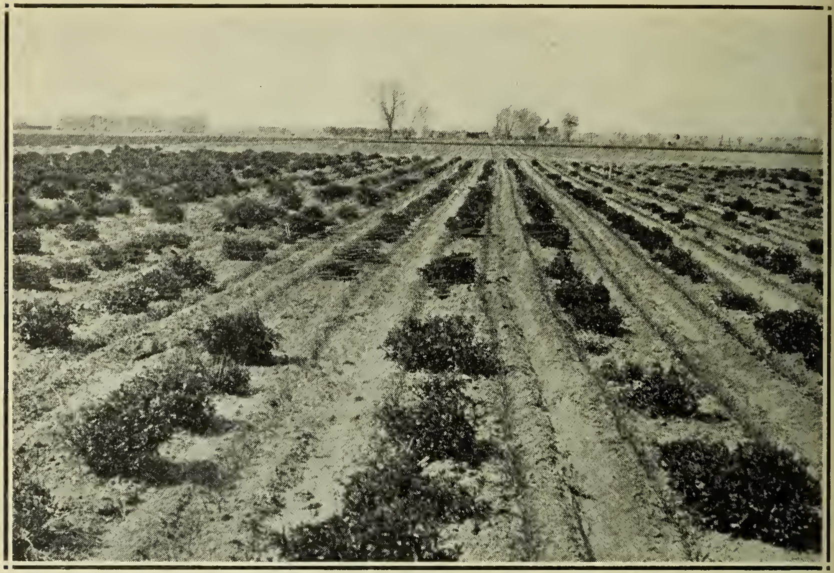
It is a well established fact that plenty of soil moisture is necessary for maximum yields of alfalfa hay. But it has also been well established that an over-abundance of moisture is not conductive to good seed production. The best seed yields seem to be secured where the moisture in the soil is somewhat limited or possibly limited at certain stages of the crop's development. But just what the moisture requirements for alfalfa seed production are has not been fully determined.

Soil moisture is extremely variable. The grower has a very limited opportunity for regulating the amount of moisture available to the crop. There are three ways in which a grower can partly control soil moisture for his alfalfa seed crop:

1. **By selecting a field properly located** in relation to irrigation and flood water, with a soil of suitable type for retaining and giving up soil moisture.
2. **By applying water** by such methods that the soil will not be over soaked.
3. **By using types of cultivation** which will regulate soil moisture to some extent.

At the beginning of the investigation, it seemed probable that a careful canvass of all methods followed by successful alfalfa seed growers would reveal a satisfactory solution of the soil moisture problem. But after a long observational study of the question under field conditions, it is clear that the solution of the problem is complex and difficult. A few growers have found fairly successful

A view of the alfalfa nursery, where the alfalfa was given different field spacing to test the effect of different spacings on seed production.



A close-up view of the alfalfa nursery experiment upon the effect of space on seed production.

methods. These growers are producing alfalfa seed by following the methods that have been worked out empirically for their particular farm conditions. But invariably they admit that the same plan does not always succeed. Neither does the same plan succeed under different soil conditions. The different ideas of the most successful alfalfa seed growers in regard to supplying irrigation have very few points in common. Hence, any specific rule formulated for regulating the water supply is usually subject to numerous qualifying conditions.

The most **conclusive results** from field observations might be summarized in the following statements:

1. The moisture condition in the soil which seems to produce the best alfalfa seed yields appears to be a somewhat **limited water supply.** The supply must be limited so that there will be a somewhat retarded growth of forage. Yet there must be sufficient moisture for the plant to function properly during the blooming period and while the seeds are forming and maturing.

2. Excessive moisture in the soil seems to stimulate a heavy growth of forage at the expense of seed production. A **heavy rain or an over soaking irrigation at about the blooming period is usually fatal** to a high seed yield. The increased moisture induces a new growth of stems and seems to exert an abortive influence on the flowers in bloom.

3. A favorable soil and moisture condition for alfalfa seed production seems to be a **sandy to sandy loam bottomland** with a water table about six to eight feet below the surface. Under such conditions, after the alfalfa is once started, the water will rise by capillarity, thus supplying the plants without irrigation with sufficient water for good seed development. Such conditions are frequently very successful for producing good alfalfa seed yield. Sometimes a light irrigation is required in addition in order to insure seed yields. Whether or not the irrigation is required depends on soil and climatic conditions.

4. **Heavy adobe soils** that are rather impervious to moisture produce desirable alfalfa seed yields where the moisture can be supplied at the proper time and in the proper amounts. Applying water at the proper time and in proper amounts requires experience with different types of heavy soil. Some growers have reported instances where five or six irrigations were necessary to produce a successful crop of alfalfa seed on heavy adobe soil.

5. **Deep, loamy soils** that are well adapted for prolific hay yields are not, as a rule, suitable for alfalfa seed production. When an attempt is made to control moisture, the seed yields are usually uncertain and irregular.

6. Under strictly **dry land conditions** without irrigation or natural sub-irrigation from an underground water table, alfalfa seed production is usually a flat failure, with the climatic conditions common to Colorado upland dry farming. On very favorable soils, with a rainfall of 18 to 20 inches, fairly good results in seed production have been secured.

These rather indefinite conclusions have been drawn from the field observations. In order to get more definite results on the specific question, "What are the moisture requirements for alfalfa seed production," several experiments have been tried by applying different amounts of water at different times on alfalfa produced for seed.

The first experiment was tried on a uniform field of alfalfa that had been sown in rows. The soil was uniform. The field of alfalfa had been developed from a single selection. This made all conditions as nearly uniform as one could reasonably expect under field conditions.

Fifty rows in the field were divided into five sections of ten rows each. The first section was left unirrigated. The second section had irrigation water run in small furrows. The water ran about twenty minutes. The third section had the water running in the rows about one hour. The fourth section had the water running about two hours. The fifth and last section had the water running thru the rows about five hours. These different irrigations provided a large range in the amount of water applied to the different sections.

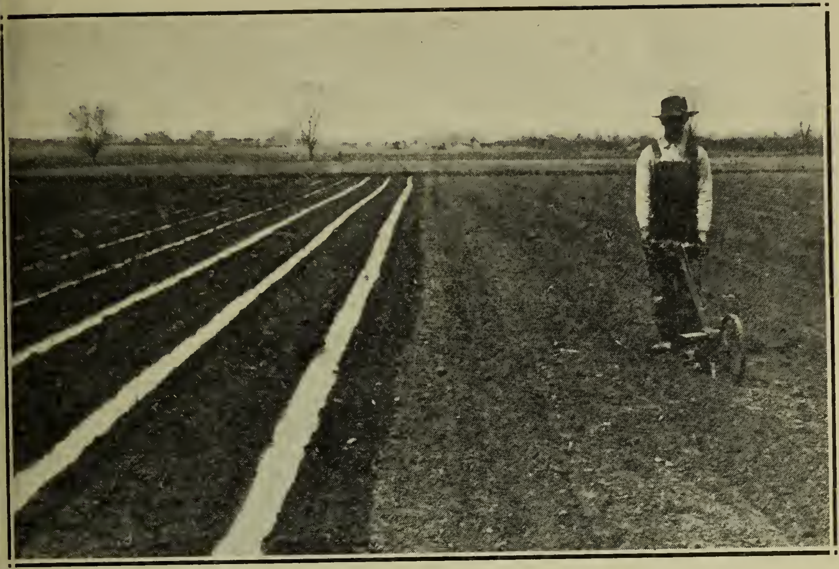
In this experiment there was practically no difference in seed formation between any of the five sections. The unirrigated section seemed to be equally as good as the others. The only difference noticed between these five different applications of water was that the section where the water ran five hours gave a **slightly higher yield in forage** than the unirrigated section.

These results apparently indicated that all the plants might be receiving subsoil water. Investigation with the soil auger proved that moisture was rising by capillarity from an underground water table which was 12 feet below the surface.

Two other similar tests have been conducted on the Experiment Station at Rocky Ford. Several different comparative moisture tests were made by alfalfa seed growers. The results of these experiments have not shown any consistent relation between alfalfa seed setting and any limit in the amount of moisture applied to the alfalfa crop.

In general, a limited amount of water seems better for the production of alfalfa seed than a larger amount. But it sometimes

A field of dry land alfalfa planted in rows for seed production. While this field is on dry land, it receives some water from an underground water table approximately 8 feet below the surface.



One method of laying off a field with irrigation for the rows where alfalfa is to be seeded in rows. The same method may be used to seed alfalfa in narrow beds. The ground is soaked by running water in the irrigation furrows.

happens that alfalfa plants growing on ditch banks, where the soils are continuously wet, will give good sets of seed. Such contradictory evidence is hard to explain. But it seems that climatic conditions and a number of undetermined factors have more to do with the question of successful seed setting than any particular amount of water.

Another observation in this connection which is difficult to explain can be found almost any year in almost any field left for seed. Frequently in such fields one portion will fail to receive enough moisture on account of the ground being too high or the water not being run long enough in spots. Near such spots, portions of ground will be found frequently where the soil becomes too wet on account of the ground being at a lower level. Such low levels will collect the water until the soil becomes so wet that the alfalfa will grow too rank for seed production, while the dry spots will not have water enough to produce seed yields.

It would seem that between these two extremes, there should be a zone where the moisture supply would be just right for successful seed production. But such a zone is seldom found.

This would indicate that seed setting in alfalfa is not dependent solely on any definite amount of soil moisture. Consequently, there must be other very important factors influencing seed production.

But the efforts to determine the role of soil moisture in seed production did not end with the above experiments. An experiment was planned to control all the water available to the plants by cutting off a possible subsoil supply.

To carry out this experiment, 24 cement lined soil pits were constructed, each four feet long by two feet wide by four feet deep. The pits were dug oval shaped. The walls and bottom were plastered with cement and made water tight by several coatings of cement. The soil from each pit was replaced. As soon as the soil was well settled, two alfalfa plants were transplanted into each pit. These transplanted plants had all been propagated by crown cuttings from two large stooled Grimm alfalfa plants. Thus, the plants in the separate pits each had the same inheritance, the same inherent seed setting tendencies, because they were parts of the same original mother plant.

The plan was to get the plants established in each soil pot under as uniform conditions as possible for the first season. Then, during the second season, it was proposed to supply a series of different amounts of water to the different soil pots. The plan was carried out on two series or in duplicate sets, according to the following tabular arrangement. The first application was made April 25, 1916, at the time the plants began to show the first signs of a need of water. The plants in all the soil pots were very nearly uniform in size.

A field of Baltic alfalfa planted in rows with a view to seed production. On the right are shown rows of alfalfa alternating with rows of grain. The grain was planted with the idea of reducing the amount of water which the alfalfa would receive, in the hopes that it would increase seed production. The results were entirely unsatisfactory.

Irrigating alfalfa in rows. In this test, the irrigation water was allowed to soak into the soil for different lengths of time in an attempt to determine the proper moisture conditions for best seed production.

Table of Amounts of Water Applied in Series A and B—Soil Pots

Plants in soil pot No. 1 received 1 quart of water every 30 days
Plants in soil pot No. 2 received 1 quart of water every 20 days
Plants in soil pot No. 3 received 1 quart of water every 10 days
Plants in soil pot No. 4 received 4 quarts of water every 30 days
Plants in soil pot No. 5 received 4 quarts of water every 20 days
Plants in soil pot No. 6 received 4 quarts of water every 10 days
Plants in soil pot No. 7 received 8 quarts of water every 30 days
Plants in soil pot No. 8 received 8 quarts of water every 20 days
Plants in soil pot No. 9 received 8 quarts of water every 10 days
Plants in soil pot No. 10 received 12 quarts of water every 30 days
Plants in soil pot No. 11 received 12 quarts of water every 20 days
Plants in soil pot No. 12 received 12 quarts of water every 10 days

In addition to the water applied, each soil pot received the normal precipitation for the season. This proved to be an insufficient amount to affect the experiment.

The different quantities of water applied to the different plants resulted in a forage development about in proportion to the relative amounts of water applied. The lightest application of one quart every thirty days was just about sufficient to keep the plants alive. As the amount of water applied was increased, the forage growth was increased. The heaviest application of twelve quarts every ten days produced practically a normal sized alfalfa plant. But the effect on seed production could not be detected as all of the plants seemed to set seed in about the same manner. The amount of seed set was in about the same ratio as the size of the plant. **The experiment did not show that alfalfa seed yields could be controlled by the application of any definite amount of water.**

An effort was made to repeat the experiment the following season. But for some reason the plants in the different soil pots developed great irregularity in growth. It is possible the irregular, abnormal growth was due to differences in root growth, the results of irregular settling of the soil in the pots.

During the season of 1919 several plants in these pots were supplied with excessive amounts of water. The soil was nearly saturated every week or ten days. In spite of the fact that all other alfalfa seed tests on the Experiment Station failed under field conditions in the season of 1919, the plants in the cement pots which received the heavy application of water all set seed fairly well.

The failure of the alfalfa seed under field conditions was thot to be due to abnormally wet conditions during the spring and summer months. Yet the plants growing in the open cement pots, which received the same precipitation and in addition heavy applications of irrigation water, were not apparently reduced in seed production by the excessive water. Again this seems to indicate that there are

A field of alfalfa sown in thick drill rows. Seeding was done with an ordinary seeder, getting results much the same as would be had by using a drill having the hoes spaced 7 or 8 inches. In this method of seeding, furrows for irrigation are spaced every three feet. This makes it possible to control the irrigation water so as to get the alfalfa as small an irrigation or make it as wet as is desired.

The most common method of irrigating alfalfa by flooding from field laterals. This method is not well adapted for seed production. On soils suitable for this method of irrigation, it is well adapted for hay production.

other factors influencing seed setting besides any definite moisture supply.

The most practical conclusions to draw from the investigation on the effect of different supplies of moisture might be summed up in the statement, "alfalfa intended for seed production should be supplied with the minimum amount of moisture that will insure a medium growth of forage and provide an adequate supply of water to insure the maturity of the seed." To accomplish this, the grower must become familiar with his farm soil conditions. He must learn how to handle his soils so as to control the moisture.

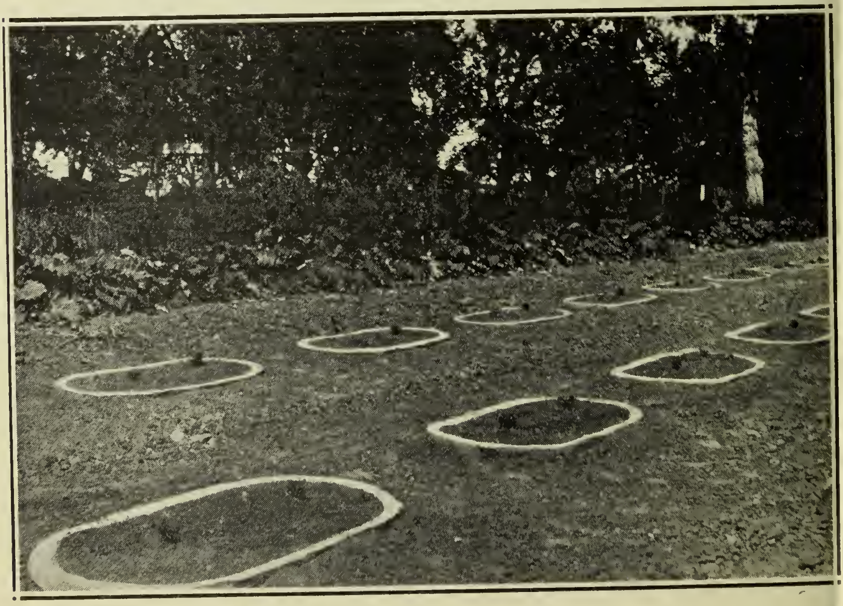
CULTURAL CARE AND METHODS TO INSURE SEED PRODUCTION

Many successful alfalfa seed crops have been attributed to the plan of pasturing the alfalfa with livestock late in the spring. The argument advanced was that the first growth which usually starts in the spring is exhausted by being pastured off. It is thot that the growth that follows when the grazing livestock is removed, about the middle of May, will be somewhat dwarfed and thus more inclined to set seed. Many successful crops of alfalfa seed would seem to warrant this conclusion. However, the investigations on this point are not conclusive. Experiments have been carried on several years where the first growth of alfalfa have been clipped off in the spring. Various plans of grazing have been tried out in comparison. The tests have been duplicated for several seasons. The results do not show that grazing off the first growth will stop alfalfa seed failure. Some seasons the first crop growth will set best with seed. In other seasons, the second growth seems to be more favorable. These varying results are attributed to varying climatic conditions.

The **effect of cultivation** on seed production has also been the subject of investigation. Tests of different degrees of cultivation have been tried out on fields of alfalfa grown in rows, where a portion was left uncultivated, a portion cultivated lightly, and a third portion cultivated deeply. So far as seed production was concerned, no difference could be seen whether the soil was cultivated or not. Cultivation seems to aid in conserving moisture. But cultivation leaves a loose surface soil, which is seriously objectionable in an alfalfa seed field. The loose soil and gravel is likely to be picked up with the crop when the crop is harvested. Loose soil and gravel mixed with the seed is difficult to separate. It often damages the alfalfa huller in thrashing.

THE EFFECT OF SPACE OCCUPIED BY THE PLANTS ON SEED PRODUCTION

It is generally conceded by alfalfa seed growers that a thin stand of alfalfa gives the best results in seed production. A thick stand



A close-up view of the cement pots used to test out the effect of different applications of water on seed yields.

A view of the series of cement pots used to test the effect of different amounts of water applied on seed yields. This view was taken the second year of the tests.

limits the bloom to the tips of the plants, while a thin stand exposes a larger proportion of the plant to light and air, thus permitting a greater amount of bloom on the scattered branches. The greater amount of bloom on the thin stand enables a heavier seed yield to be produced if other conditions are right.

Space effect in its influence on alfalfa seed production has been under investigation in a series of experiments. The alfalfa was planted in rows spaced at different distances. The plants in the row were thinned out to different row spacings. The space alloted to each plant ranged from 18 to 20 square inches to as many square feet. The results from these experiments indicated that a thin stand is necessary. But it was also evident that lack of space was not the general cause of failure of alfalfa to produce seed. Where plants were given practically unlimited space, there were still approximately the same percentage of plants which failed to produce seed. It has been observed that plants which grow in large, open spaces will sometimes produce seed prolifically, especially on the stems which lie close to the ground. Often the other branches of the plants are not especially well set with seed. There is some doubt whether space is primarily the cause of this extra good seed setting near the ground. (This observation will be referred to again under the topic of "The Influence of Temperature on Seed Yields.")

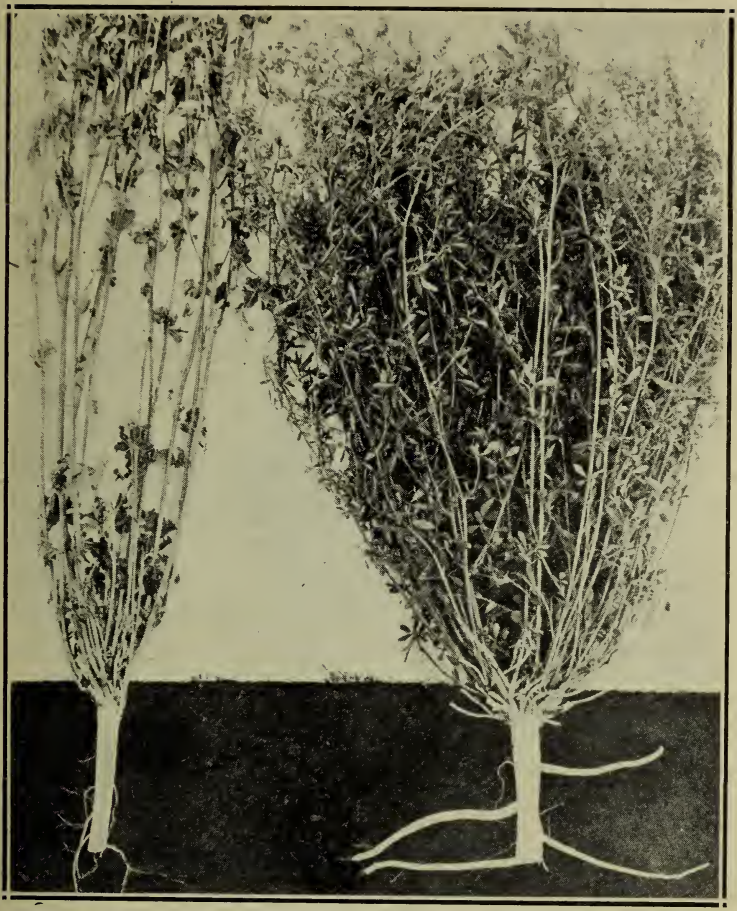
The conclusion on the studies of space effect is that a **uniform, thin stand is desirable** for best results in alfalfa seed production. The stand must be thin enough to give the plants a maximum opportunity to bloom as fully as possible.

GROWING ALFALFA IN ROWS FOR SEED PRODUCTION

Many growers have sown alfalfa in rows, expecting to cultivate. The object in sowing in rows was to secure a uniform, thin stand for seed production. This method of seeding has been highly successful in securing a uniform, thin stand of plants. But it has not succeeded in solving the seed problem.

There are some very serious objections to handling alfalfa in rows, especially if the rows are widely spaced. The chief difficulty is encountered in handling the crop with farm machinery, if the rows are thirty to forty inches apart. The soil between the rows will become low as it is washed out by rain or irrigation or blown out and drifted into the crowns. These causes leave the field rough and uneven. On such land it is very difficult to harvest a crop. The outer branches from the row will lie over on the ground,

A field of Grimm alfalfa seeded in 20-inch rows. On this field the tests on cultivation, root pruning and top clipping were carried out.



A comparison of both crown development and habit of growth of northern and southern types of alfalfa at the end of the first season's growth. The southern type is on the left, the northern at the right.

making mowing difficult. If cultivation is neglected, a field of alfalfa in wide rows will become a veritable weed patch.

The principal arguments in favor of seeding alfalfa in rows are to secure a **uniform, thin stand** and provide a means of **regulating irrigation** in furrows between the rows. If the rows are not too far apart, the plan succeeds fairly well. In rows twenty inches apart, the stems will interlock and support themselves so that the crop may be harvested fairly well. But even with twenty-inch rows, the ground may be somewhat rough.

A more suitable method for seeding alfalfa so as to regulate the application of irrigation is to sow the seed in closely spaced rows or drills, say six to eight inches apart. At intervals of about every thirty inches or so an open space may be left for an irrigation furrow. This is equivalent to seeding in narrow beds with a crease or small irrigation furrow between the beds. The plan lends itself either to hay or seed production. The seeding may be made light or heavy as desired. For seed production, **one to three pounds** of good seed should furnish a stand of plants sufficient for highest seed yields. **Eight to ten pounds** would be better adapted for hay production.

THE RELATION OF BEES AND OTHER INSECTS TO ALFALFA SEED YIELDS

There is a theory that alfalfa seed yields are dependent on the presence of bees or other insects. This seems to be based on old textbooks, which teach that the fertilization of alfalfa flowers is dependent on the ''tripping'' by bees of the flower mechanism that envelops stamens and pistil.

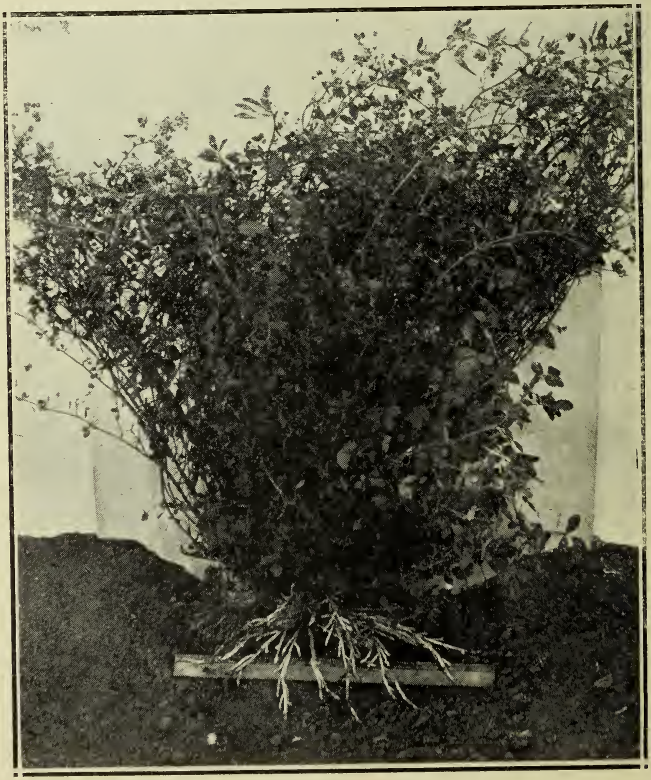
A typical plant of the southern or non-hardy type of alfalfa.

A typical plant of the common alfalfa.

An experiment was conducted to determine to what extent alfalfa seed failures were due to bees and other insects. A number of alfalfa plants were protected with screen cages before the blooming time. These plants were compared in seed yields with similar plants which were given the same care except that they were not covered with screens. The results were that some of the plants under screens set well with seed. Some did not. This was also true of the plants not covered. The experiment was repeated two years in succession, with practically the same results. That is, **there was no clear evidence that bees or other insects were essential to alfalfa seed production**. It is possible, under field conditions, bees may have an influence in slightly assisting fertilization of alfalfa bloom. However, the covered experiments showed that fertilization could take place without the insects and did so take place.

An experiment was carried on to determine the effect of artificial "tripping" of flowers. The branches of a number of selected plants were divided. The flowers on half of each plant were "tripped" by hand. The other half of the flowers of each plant were unmolested. The results here were very similar to the results under the covering of screens. Some produced seed and some did not. There was practically no difference in seed yields resulting from hand "tripping" of the flowers. Observations have been carefully made to try and determine if the flowers on plants that were prolifically setting were any more likely to be "tripped" than flowers which were failing to set seed. While some plants seemed to have more "tripped" flowers than others, it could not be seen that the "tripped" flowers were more inclined to set seed. Many flowers were observed which did not "trip." They remained untripped until the bloom withered. Yet many such flowers did set seed. There is a possibility, of course, that the "tripping" may have occured when the bloom began to wither.

The presence of large numbers of the small insect know as



A very good typical representative of the northern or hardy type of alfalfa.

There is a very wide range in type of plants grown from common commercial seed. The plants shown are typical variations obtained from the planting of common commercial seed.

"thrips" has been regarded by some as an important factor in causing alfalfa seed failures. Careful examination of flowers on plants that were setting seed successfully showed that the thrips were as abundant on such flowers as on blooms where no seed or little seed was setting.

From these investigations, it seems probable that **some of the injury to alfalfa bloom is due to the thrips.** There is some injury from other insects. But it is hardly possible that these injuries are the prime cause of seed failure. This conclusion is reached because many of the worst injured blooms set fairly well with seed.

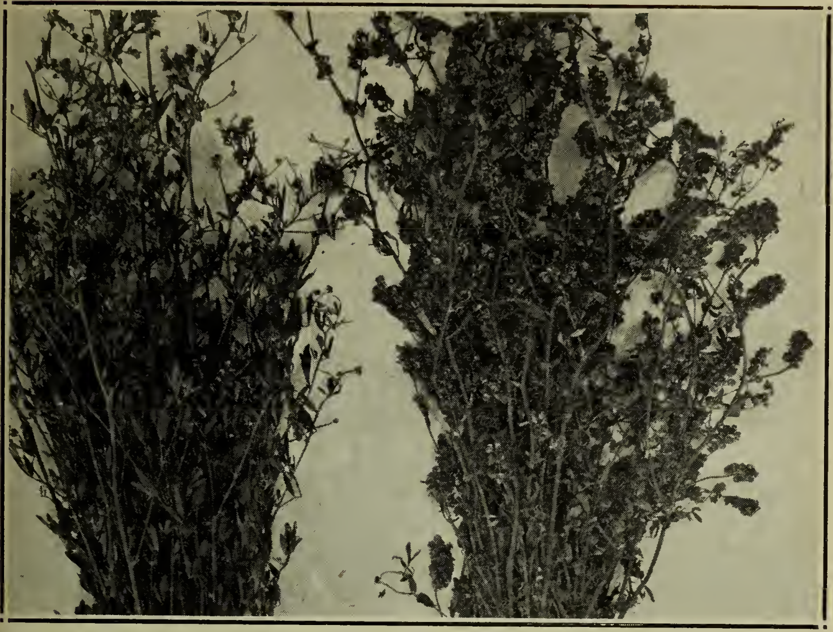
In seasons of severe alfalfa seed failure, it is usually possible to find a few plants which set seed perfectly, even where the surrounding plants in the field are a dismal failure. Such results in the midst of failure is the paradox in the alfalfa seed problem. It is difficult to harmonize these results with any theory of insect activities in relation to alfalfa seed setting. If beneficial insects are essential to fertilization of the alfalfa flowers, it would not seem possible that a few plants would be well fertilized, while the mass of adjacent plants were not. On the other hand, if injuries were responsible for seed failures, it would seem incredible that some plants would escape injury entirely, that their flowers should become well fertilized, when the surrounding plants would fail completely on account of insect injury.

CLIMATIC CONDITIONS, HEAT AND ITS RELATION TO SEED YIELDS

As previously mentioned, it has been observed frequently that alfalfa branches which bend over and lie closely to the bare ground sometimes set heavily with seed, when the balance of the same plant sets poorly. These branches close to the ground are not only exposed to hot sunlight, but are also exposed to radiated heat from the soil below. A notable instance of this kind occurred on the Experiment Station Farm at Rocky Ford in the fall of 1919,

An irrigation ditch that had not been used all summer had a row of alfalfa growing on its north bank. The ditch had been cleaned out with a ditching "A." This made a dry, sandy, sloping bank next to the alfalfa row. The lower branches from this row dropped over into the ditch. These branches thruout the length of the ditch (about 300 feet) all set heavily with seed. The branches nearest the ground were best filled with seed. The balance of the branches of the plants in the row was practically barren of seed.

Plants developed from a single mother plant, thus producing a selected strain showing great uniformity in their development and habits of growth. The above plants all came from one selected strain.



A contrast in seed setting ability on plants grown under exactly the same conditions. The plant at the right is heavily set with seed, that at the left almost devoid of seed.

It was clearly evident that the cause for this good seed setting was entirely local. The effect was limited to the branches that hung over into the ditch. The ditch was perfectly dry. It seemed evident that heat was the important influence peculiar to these branches in the ditch. The only two factors which were different for the branches out of the ditch and the branches in the ditch were heat and light. The free circulation of air would be somewhat obstructed by the bank and surrounding vegetation. The dry, sandy soil would reflect both heat and light. The air and branches in the ditch would become very warm during the heat of the day. This instance was the **first practical evidence of the effect of some one cause as a prime factor in prolific seed production** which has occurred in the past 16 years in which alfalfa seed production has been under investigation.

The effect of this observation may not be easy to analyze. But it is evident that there is some physiological relationship between the effects of heat or heat and light and the efficient fertilization of alfalfa flowers, which is equivalent to saying that there must be some relationship of heat and light and the proper functioning of the processes of reproduction. It at least gives a clue for further investigations. Climatic conditions are evidently the most potent influences affecting seed production. But as these are beyond the control of man, it is apparent that seed production must be achieved by adapting the alfalfa or alfalfa growing conditions to meet the climatic conditions. This line seems to offer the most feasible promise in future investigations of the alfalfa seed problems.

SOIL FERTILITY AND ITS EFFECT ON ALFALFA SEED PRODUCTION

Investigation of the effects of different fertilizers on alfalfa seed production has been omitted or overlooked, probably because of the many successful seed yields under conditions where no special soil fertility was provided.

If a record of alfalfa seed yields in the Arkansas Valley could be reviewed, it would be noted that 600 to 900 pounds per acre were not uncommon yields about 25 years ago. The soils of the Arkansas Valley were nearly virgin at that time. The soils at that time were more or less deficient in nitrates and organic matter.

In recent years, alfalfa seed yields have greatly fallen off, so that 180 to 250 pounds per acre is regarded as a fair seed yield.

There are two general farm conditions that have undoubtedly

A field of alfalfa seeded in rows. It is easy to see the dry spots. Around these dry spots there was a range of moisture, varying from too dry for production up to too wet, yet there was no apparent evidence of a zone of good seed setting anywhere between these two ranges.

A close-up view of a dry spot. In the center of the spot conditions were too dry for seed production or hay production. Between the center of the spot and the edge, there was no zone of seed setting, altho there was a zone of difference in the moisture content, varying quite uniformily from the driest of the center to the wettest of the outer edge.

changed: 1. With the general practice of irrigation, the **water table has risen** on the old irrigated lands. 2. Soil **nitrates have increased** in the soils to a considerable extent.

It is now well established that much of the soil in the Arkansas Valley is rather overcharged with nitrates. These nitrates are evidently developed in some soils and carried to others by irrigation waters. This fact has aroused a suspicion that an excess of nitrates may be partly responsible for decreased alfalfa seed yields. In fact, there are strong evidences that this is the case. For the past two years, alfalfa on the experimental plats has failed to bloom normally. There was hardly any bloom at all. The soil in these plats is know to be strong in nitrates. Alfalfa, in its seed setting traits, seems to behave much as plants overfed with nitrates. This suggests that the physiological effect of different fertilizers be made a line of future investigation.

SUMMARY

1. There is a difference in the inherent seed setting tendency of different strains of alfalfa. The southern strains seem to be strongest

in this respect. But the southern strains are not adapted to our climatic conditions. They are not sufficiently hardy.

2. Seed selection for prolific seed yield improves the ability of the selected stocks to produce seed yields. But the improvement is not sufficient to solve the problem.

3. The amount of moisture for alfalfa seed production should be regulated to such an amount that a minimum amount of forage growth results and still have water enough to fill and mature the seed. This virtually amounts to what might be called a medium quantity.

4. Pasturing off the first growth late in the spring has apparently stimulated good seed yields. Good seed yields seem to be coupled with such an arrangement of the irrigation system as to regulate the amount of water and hold it close to a minimum requirement. Apparently this is best done by having small irrigation furrows about every thirty inches and thus irrigate by the furrow method.

5. A thin stand of plants is necessary for the best seed production results. A uniform stand is essential. A plant to every one or two square feet is about right if the stand is uniform.

6. There are serious objections to growing alfalfa in rows. The most serious objection is the difficulty in handling the crop with machinery.

7. There is very little evidence that bees are essential to alfalfa seed yields.

8. Dry climatic conditions with high temperatures seem to be among the most essential requirements for successful alfalfa seed production.

9. The effect of fertilizers or nutritive substances on alfalfa seed production has not been investigated. There are indications which point to soil nitrates in excessive quantities as a serious cause of poor seed yields in many irrigated regions.

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Bulletin 258 February, 1921

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

THE FIXATION OF NITROGEN IN COLORADO SOILS
A Study of the Wellington District, Larimer County, Colorado

By
Wm. P. HEADDEN

1945

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1921

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THE FIXATION OF NITROGEN IN COLORADO SOILS

By WM. P. HEADDEN

It is now 8 years since our last publication under this title, "The Fixation of Nitrogen in Colorado Soils", appeared and the content of our previous publications on this subject may be unknown to some reader of this. It is therefore proper to give a concise statement of the principal points already presented in order that the relation of this bulletin to the general question may be evident.

Bulletins 155 and 178 present the facts relative to the occurrence of nitrates in our soils, often in very excessive quantities. This fact is established by many instances in which the amount of nitrates, usually given, as a matter of convenience, as sodic nitrate, but sometimes as mixtures of calcic, magnesic, potassic and sodic nitrates in the statement of the analyses, ranged from a few hundredths of one percent up to more than six percent of the air-dried soil. Twenty-seven separate occurrences in soils and two in well waters were discussed in order to establish the fact that such occurrences are not simply scientific curiosities and to show that their distribution is general throughout a very large territory.

In these bulletins is also presented an explanation of their formation. It was first shown by a process of elimination that these nitrates are not derived from the waters used for irrigation nor from ground-waters. Further, that the very prevalent, popular view, that these salts are brought up from beneath, is not tenable. Further, that the facts in regard to the occurrence of nitrates in the rock strata do not permit us to assume these as the source of these nitrates. Further, that the manner of these occurrences, often being confined to very limited areas, and in such positions that we cannot explain them on the assumption that the nitrates have been concentrated in these places by being washed out of other lands, indicate a local origin. Such explanations having been eliminated, we concluded that the occurrence of these excessive quantities of nitrates were exaggerated instances of a process going on in our soils, to wit, that these nitrates are being formed in the soil. It was evident that these areas, at first designated as "spots" because of their small size,—and this term, nitre-spots, was retained throughout, even when an area of 8, 10 or more acres was indicated,—were very much richer in nitrogen than ordinary soil and it was suggested that this nitrogen was derived from the air by the micro-flora of the soil. Later the power of these soils to fix nitrogen, i.e., to take it from the air, was shown by direct experiment. The amounts fixed under laboratory conditions were very considerable. The results actually obtained showed that, had the rate of fixation continued for one year, the top two inches of soil would have appropriated as much nitrogen as is contained in 2.8 tons of sodic nitrate. The only new feature in this suggestion was that this fixation may be accomplished on so large a scale and with such an intensity.

We also showed that nitrification, as well as fixation, goes on very rapidly in these soils. The maximum increase obtained by laboratory experiments in the amount of nitrogen in the form of nitrates was 138 percent in 48 days. Observations were made on the increase of this form of nitrogen in the field for several months—from the beginning of August till the latter part of November. Our results are given in pounds per acre of sodic nitrate equivalent to the nitric nitrogen found in the top 4 feet of the soil. This land had been cropped to wheat. We found for four sections taken 1 August, 91.9, 51.7, 51.4 and 38.9 pounds of sodic nitrate; on 22 November, the same plots yielded 179.0, 136.3, 154.3, and 191.6 pounds. The August samples were taken just at the time the crop ripened and the November ones almost 4 months later. The crop was harvested 10 August. These results show that nitrification goes on rapidly in the soil as soon as the crop is removed. We see that we have, in practically 3½ months, an increase of from two to fivefold in this form of nitrogen.

The distribution of this nitric nitrogen was also determined both in cropped land and in the nitre-spots. It is the latter only that interests us at this time. Bulletin 186 presents a study of this phase of the subject. The question of general distribution and the possibility of subsequent concentration to account for the nitrates found in these spots is considered at length and the conclusion arrived at, that we have no grounds for assuming that such concentrations have taken place, on the contrary, we showed that in the case of some areas, very rich in nitrates, such concentrations could not have taken place. Further, that these nitrates and our ordinary alkalis do not have a common origin. Further that it is only the surface portions of these nitre-spots that are excessively rich in nitrates. It is, however, recognized that they may be washed down into the deeper portions of the soil or into the underground waters by irrigation or by rain-water. The lateral distribution is often very sharply defined, a variation from 7,077.0 to 16.0 p.p.m. of nitric nitrogen was found within 16 feet; again from 6,444.5 to 2.0 p.p.m. within 20 feet. These sharp limits can generally be recognized by the color and other physical properties of the soil.

In this connection, the ground- and drain-waters were investigated. When these underlie or come from beneath nitre-areas, they may contain nitrates, otherwise this is not the case. In no instance have we found the least justification for believing or assuming that the nitre-spots have been produced by these agencies.

It is claimed that Colorado soils very generally possess both high fixing and nitrifying efficiencies, so high that the quality of crops may be affected even to an injurious extent. Bulletin 183 presents a study of this feature of the problem as it affects sugar beets.

In prosecuting a "Study of Colorado Wheats" we again came in contact with this question which proves as important in connection with the wheat as with the beet crop.

Of course, there has never been any question of the importance of nitrates in the growing of crops and this is in no manner at issue in this study. The question is wholly one of the quantity of nitrates present and the source of the nitrogen that they contain.

OBJECT OF THIS BULLETIN

The object of this bulletin is to present the facts as existing in a new district, that of Wellington, about 14 miles north and east of Fort Collins. This district lies in the valley of Box Elder creek, a small tributary of the Poudre river.

Our attention was directed to this occurrence by the fact that well-waters brought to the station laboratory from this section were sometimes found to be relatively rich in nitrates. In one instance a ranchman brought in a sample of water and a portion of a residue that he had obtained by evaporating some of the water to dryness. This water was very rich in total solids and especially in nitrates. He had lost 17 head of cattle by allowing them to drink this water. While the water was heavily charged with ordinary "alkali" salts, it was not richer in these than other waters that are used without injury to stock. The unusual feature in the water was the presence of nitrates. The water was evidently unfit for any farm use. Inquiry elicited the fact that other wells in that section had also caused the death of stock, especially when they were first brought in from the range.

This section has been brought under irrigation within comparatively recent years. It is certainly not yet 25 years since this happened. The death of the cattle, due to the drinking of this well-water, occured 6 or 7 years ago and a well-water, in what is known to me as the Boon place, had caused the death of some cattle each year for some years before this, so these conditions had established themselves in less than 15 years after the section had been brought under irrigation. It must not be inferred from this statement that there is any proof at all that irrigation has any proven, direct, and necessary connection with the formation of these nitrates. A certain amount of moisture is necessary. Irrigation plays no other part than to supply this moisture. Previous to the incident of the killing of the cattle by this water, the occurrence of nitrates in this particular section was unknown to me, though I knew of their occurrence in other sections of our immediate neighborhood. A superficial examination of this land sufficed to convince me that it presented another instance of a remarkable amount of nitrates in the surface soil.

A few years later other samples of well-waters carrying nitrates were brought in to us. This occurred so frequently that it seemed to be worth the while to study the section to ascertain the relation existing between the occurrences in well-waters and in the surface soils. This attempt has led to the preparation of this bulletin, whose object it is to give the general facts of this, heretofore, undescribed occurrence of nitrates; to present the relation between the occurrence of these salts in the soil and the well-waters; and also to present in so far as possible the composition of waters obtained from deep wells.

PLAN OF STUDY

The plan of study was in the first place to gather samples of surface soil and of waters from shallow wells, on an east and west line across the district, 16 miles, and also on a north and south line through it, 13 miles. In the first line we have the section of one valley and the western portion of one and the eastern portion of a third one. The north and south line gave us a section of the central valley. This preliminary work revealed the fact that we had to do with only one principal area on the east and west line which was rather more than 2 miles wide, but on the north and south line it was broken into subordinate areas for the greater portion of the line. We afterwards sampled the soil and water in a section on this line 2 miles wide and 8 miles long.

To give the data of this preliminary work would show nothing that cannot be stated in a few words. Starting at our eastern limit we found no nitrates in either the soil or water samples, till we got within about 3½ miles of Wellington, for the next 2 or 2½ miles the nitrates were abundant, but there were none in either the waters or soils westward till we reached the region of Dry Creek, just west of Waverly, where they occurred again, but irregularly and much less abundantly than east of Wellington. The Waverly district did not present sufficient interest to justify further study at the time. While we found some nitrates in this section, the more striking occurrence was that of small areas rich in calcic chlorid. These were neither large nor numerous enough to be of much interest to us as we know of another section, a district in the San Luis Valley, in which such areas are larger, more abundant, as rich or richer and apparently more difficult to account for than these. In the case of these occurrences near Waverly, Larimer County, it might be contended that a possible or even probable explanation can be found in the history of the section, i.e., as there is still a small cattle industry in the section which formerly was predominant throughout the country—these spots where the calcic chlorid is now found might be places where salt had been put out for the cattle. A successful refutation of such an assertion would be difficult even if the assertion is not true. While it is easy to show that the reaction between calcic sulfate or carbonate and salt may form calcic chlorid, I scarcely believe that these areas represent old salting spots. This is not the question which concerns us now and we have said, perhaps unwisely, more about this than its importance justifies.

The history of our acquaintance with the occurrences of nitrates in the Wellington district, though imperfectly given, establishes the fact that the matter is of some importance, and that the conditions have persisted long enough to show that they are established and are not temporary as I have known them to be in a few cases. The preliminary work or survey of the district showed that a single area of 16 square miles is involved and that there are smaller areas lying outside of this.

WATER-SOLUBLE SALTS IN SOILS

We shall give only a few analyses of the water-soluble portion of these soils as we have published a great many such in connection with this general subject, but it is advisable, per haps, necessary, to give a few to give the reader an idea of the richness of some of these soils in nitrates and to present the peculiarities in the composition of the mass of soluble salts present in the soils.

DIFFICULTIES IN ANALYZING EXRTACTS

The difficulties met with in making these analyses are serious enough to justify mention of the fact in the text and not relegate it to a foot-note. We have found it necessary in other publications to state that the analyses had been calculated to one hundred. This has never meant that the determination of any constituent had been omitted but usually that owing to the organic matter and the nature of the salts present the errors were distributed. The determination of the organic matter was considered the least reliable and of the least importance and was, therefore, bracketed or rejected.

The analysis of an ordinary alkali may not be either an important or a high grade piece of work, still it may prove to be a difficult matter, not to make it add up to 100 with only an allowable deviation, but to make the acids and bases balance. It is a very common experience to find that the bases are in excess of the amount required by the acids present, and a repetition of the whole analysis will probably fail to change this result. If there are chlorids of calcium and magnesium or nitrates of these elements present, it is possible that basic salts may be formed on evaporation, and drying at a higher temperature is out of the question. In manipulating these soil extracts I have frequently found it impossible to obtain a solid residue without easily perceptible decomposition of the nitrates. This difficulty has proven so great that in some cases we have used the aqueous extract of the soil without concentration which presents other difficulties. Evaporation under reduced pressure was not feasible.

It is fortunate that in this work a slight misstatement in regard to the absolute quantities of the respective salts present or their relative proportions does not conceal, or seriously distort the main facts. If the question had to be decided by any narrow margin in the quantity or so nice an adjustment of the relations that the errors introduced by this manner of treating the results became important, the question itself would disappear. The facts themselves are so big and evident that even great big inaccuracies cannot conceal nor in any serious degree affect them.

The first sample of soil presented represents a piece of ground that had been planted to beets the preceding year, but the crop was for the most part a failure. The surface of the ground was black and shining. This field was separated from a tract of virgin prairie-land by the public road. We did not attempt to ascertain the height of the water plane, because there was a well at the end of the tract, probably 300 feet to the east of the point where the sample was taken and only a very little, if any, higher. This well is 25 feet deep and had at the time apparently about 5 feet of water in it. While this may indicate the water level for this land in a general way, it cannot be taken as indicating that the water plane in the land where we took the soil sample may not have been materially higher. My judgment is that it was because I have found at other points that there may be small basin shaped areas of varying size with impervious bottoms which may be almost filled with water, but if one passes through this bottom in digging a hole, little or no water will come in below it.

I make mention of this fact because the water plane in the well may be, for the reason here stated, misleading in regard to the height of the water plane where the sample was taken and I did not make this an object of study at this point. This sample was collected about 4 years ago and this land has continued to grow worse during the intervening period. I do not know the history of this land nor how long it had been under irrigation at the time the sample was taken. There is very little land under the irrigating ditch to the east or north of this, so that the amount of seepage that may flow into or through this land cannot under any circumstances be very great. It is true that there may be leakage from the irrigating ditch, which carries water at times. I do not know how long it carries water each season nor the amount of leakage. The ditch is located a little to the east of this point and I believe that there is no irrigated land beyond this ditch to the east. The east flank of the valley rises rather abruptly only a little way, from ½ to 2 miles, to the east of this and beyond it lies a dry-land country.

ANALYSIS OF WATER-SOLUBLE, SOIL LABORATORY NO. 2369

The water-soluble equalled 11.03 percent.

	Percent
Calcic sulfate	11.345
Calcic chlorid	40.444
Magnesic chlorid	18.736
Magnesic nitrate	14.946
Potassic nitrate	4.816
Sodic nitrate	9.057
Sodic silicate	0.284
Ferric and Aluminic oxids	0.149
Manganic oxid (br)	0.223
	100.000

The next soil given was collected along the edge and from a corner of a field that was still in fair condition. The surface of the soil showed all the characteristics of land affected by nitre-trouble. The water-soluble was not quite so high as in the preceding case, and the condition of the land at the time the sample was taken was not very bad.

ANALYSIS OF WATER-SOLUBLE, SOIL Laboratory No. 2368

Water soluble equaled 7.46 percent of air-dried soil.

	Percent
Calcic sulfate	10.222
Calcic chlorid	32.711
Magnesic nitrate	41.766
Calcic nitrate	6.428
Potassic nitrate	8.111
Potassic silicate	0.493
Ferric & Aluminic oxid	0.094
Manganic oxid (br)	0.175
	100.000

The third sample of soil was taken in a beet field and from the spaces between the rows. The beet tops were very large and very green. The stand was somewhat irregular, but it was a surprise to find so good a one under the conditions. One would scarcely think that the seed would germinate in such soil. The soil was black but not so wet as it appeared. We dug a hole at the edge of this field to get a sample of the ground-water. The water came in at a depth of 4 feet and below this it did not seem to come in at all. The hole was in all a little more than 5 feet deep. We had to wait an hour for the water to run in before we could get a five gallon sample.

The analysis of this soil extract gave us an unusual amount of trouble. The analysis was repeated three times with fair agreement and yet we have an excess of bases. The analyses were made on the aqueous extract without concentration.

ANALYSIS OF WATER-SOLUBLE, Soil Laboratory No. 2454

Water-soluble equaled 7.81 percent of air-dried soil.

	Percent
Calcic sulfate	7.823
Calcic chlorid	22.716
Calcic nitrate	21.551
Magnesic nitrate	38.102
Potassic nitrate	6.784
Excess as sodic oxid	3.024
	100.000

These soil samples were taken relatively close together, the most distant pair being about a mile from one another. This land shows no efflorescent salts, it is simply black and more or less shiny; in some places it is a little mealy.

SALTS IN SOIL—EXTRACTS DIFFERENT FROM ORDINARY ALKALIS

The analyses show that the salts present in these soils are wholly different from those in our ordinary alkalis. The small amount of sodic salts present is as remarkable as the very large percentage of nitrates and chlorids which are present as calcic and magnesic salts. The analytical results are such that there can be no question in regard to the order of combining the elements to form salts, there is no choice. The salts present are essentially the chlorids and nitrates of calcium and magnesium, with more potassium than we usually find in such extracts and only very small amounts of sodic salts, whereas, it is generally the case that the sodic salts are very strongly predominant. That there should be no soluble carbonates in the presence of such excessive quantities of calcic chlorid is what we should expect, but there is no reason why the sulfates of calcium and sodium should not be present. These sulfates are abundantly present throughout the Poudre Valley and in almost every other portion of the State. In fact, the sulfates are the characteristic salts of our alkalis. There is no property of the chlorids that would militate against the presence of the sulfates of either calcium or magnesium. We have one section of country not as yet discussed in any of our publications where we have calcic chlorid present as an important, and in some samples the predominant constituent of the soluble salts.

How these quantities of calcic and magnesic chlorids have been formed or can be present is by no means clear. The alkalis in the Poudre Valley carry magnesic sulfate to a larger extent than those from other sections of the State. The presence of this salt is shown by all of the analyses of alkalis and also ground-waters that we have published. Why these sulfates should be absent and the chlorids so plentiful in this section is not in any measure apparent. I do not even see how the usual explanation offered for the formation of calcic chlorid, namely, the interaction of calcic sulfate or carbonate and sodic chlorid, can apply in the present case. There is no local abundance of sodic chlorid in this district that has come to our knowledge to account for the prevalence of the calcic and magnesic chlorids.

In the other occurrences of calcic chlorid referred to, there is an abundance of these salts, sodic chlorid, calcic sulfate, calcic carbonate, sodic sulfate, with nitrates and sodic carbonate. In the Wellington District, we find comparatively little sulfate or other sodic salts associated with the calcic and magnesic chlorids, though we should expect them if these latter were formed by the action of sodic chlorid on the respective carbonates or sulfates.

GENERAL CHARACTER OF COUNTRY

The country with which we are particularly concerned is drained by the Box Elder Creek. The country does not present an even valley-floor but rather a series of depressions surrounded by ridges which serve as water sheds, cutting off the depressions from one another and rendering the drainage question a special one for each individual depression. These basins are sometimes quite small. The one in which the first sample of soil, No. 2368, was collected, is scarcely one mile in diameter. There is no drainage that I have noticed into this basin and very little out of it. I think that it could be drained but with considerable difficulty. The contour of the country and the recent date at which this section was brought under irrigation render the question of accumulation of these salts by transportation and concentration almost irrelevant.

How such easily soluble salts as the chlorids and nitrates of calcium and magnesium can be accumulated or concentrated to the extent that we here find them without the concentration of sodic salts, especially the sulfate which is so generally distributed, is difficult to understand. The universal presence of our ordinary alkalis, which are mixtures of calcic, magnesic and sodic sulfates, with chlorids and carbonates very subordinate, shows that our whole country is one big example of the concentration of the sulfates.

COMPOSITION OF ALKALIS IN THIS SECTION

It may serve a purpose if we give analyses to present these variations and to show that the peculiar composition of these extracts is not an accident confined to the two localities given, but is characteristic of this whole section. They will at least serve for comparison.

These analyses have not been published heretofore. The alkali chosen was gathered from the low lands along the Poudre River, nearly opposite the point where the Box Elder Creek joins the river.

WHITE ALKALI, POUDRE RIVER BOTTOM LAND

	Percent
Calcic sulfate	7.935
Magnesic sulfate	46.353
Sodic sulfate	41.926
Sodic chlorid	1.894
Sodic carbonate	0.756
Potassic carbonate	0.565
Sodic silicate	0.364
Ferric & Aluminic oxids	0.098
Manganic oxid (br)	0.109
	100.000

This white alkali represents an efflorescence that at times appears very abundantly on some of these bottom lands. The soils, analyses of whose water-soluble portion are given above, usually show no efflorescences, which is a marked difference. The process of efflorescing is one whereby the less soluble, easily crystallizable, salts are separated from the more soluble and less easily crystallizing ones. This accounts in a large degree for the differences in the analyses given. But the ordinary alkalis do not appear on these soils as efflorescenses nor in the analyses of the water-soluble. If the white alkalis were present in these soils they would form efflorescenses under favorable conditions. This is a fact that can be observed at some places.

The following is an effloresced, ordinary white alkali, collected from the margin of a very bad piece of ground in the Wellington District. The sample was scraped off the surface of the soil which was very wet at the time the sample was taken. The surface was very uneven and I gathered a great deal of soil with the alkali. The water-soluble portion was 13.36 percent of the air-dried sample. Under these circumstances the separation of the salts by efflorescence was probably very much better than my separation of alkali and soil. The character of the effloresced salts, however, is not in the least obscured and they are clearly the usual mixture of sulfates constituting our ordinary alkalis, with a little nitrate from the soil. The composition was as follows:

ANALYSIS OF EFFLORESCED SALTS, Laboratory No. 2602

Water soluble equaled 13.36 percent of the air-dried soil.

	Percent
Calcic sulfate	26.445
Magnesic sulfate	25.770
Sodic sulfate	42.040
Potassic chlorid	2.263
Sodic nitrate	3.482
	100.000

This analysis shows that the efflorescence on this soil at the time we collected the sample, 12 February, 1920, was essentially our ordinary alkali, a mixture of sulfates in which sodic sulfate predominated, while calcic and magnesic sulfates were present in about equal quantities; they made up one-half of the total. The small amount of nitrates probably belonged to the soil which constituted 86.0 percent of the sample as it was gathered. This and also the following sample was collected on the flank of a little knoll in a field that is rapidly becoming very bad. A portion of the field, only a little lower than that where we collected these samples, has become as good as unproductive within the past three years.

The soil of the field where the following sample was taken did not show very much efflorescence and beets had grown there in 1919, but the crop appeared to have been almost a complete failure. The soil was slightly mealy.

ANALYSIS OF WATER-SOLUBLE, SOIL Laboratory No. 2603

Water-soluble equaled 6.733 percent of soil.

	Percent
Calcic sulfate	22.720
Magnesic sulfate	37.467
Potassic sulfate	1.556
Sodic sulfate	17.518
Sodic chlorid	9.849
Sodic nitrate	10.835
Excess sodic oxid	0.046
	100.000

The last two samples were taken close together, the alkali formed a white covering on the ground when it was collected, but the ground where the soil sample was taken showed no efflorescence—only a little mealiness on the surface. The distance between the two lines on which the respective samples were taken was 25 feet. The differences in the analyses are very marked. Sodic sulfate makes up 42.0 percent of the effloresced alkali and only 17.5 percent of the soil extract. While magnesic sulfate makes up 37.5 percent of the soil extract and 25.8 percent of the alkali. The alkakli as it was gathered consisted of 86.0 percent of soil, still it carried only 3.5 percent of nitrates against 10.8 percent in the soil extract. It is true that the conditions where these samples were taken were patently different though they were taken so close together; this is the reason that the samples were taken and our object was to ascertain what differences exist between the alkali, effloresced salts, and the soil extracts under the conditions obtaining in such places. The differences are greater and more radical than we expected to find them. The differences in general, but particularly in regard to the nitrates, are very suggestive.

LARGER AREA NECESSARY TO ESTABLISH CHARACTER OF SOIL-EXTRACTS

The soils, heretofore given, are from two neighboring little valleys. The mixture of soluble salts is so unusual for our soils that it raised the question whether two or three samples which were taken from two places and these close together, represent the facts as they exist in the district. Whatever these facts may be it becomes incumbent upon us to ascertain and set them forth. For this purpose we have chosen a series of samples representing a continuous section about 4 miles long and one sample 4 or 5 miles further south but in the same line. The choice of these samples was determined by the results obtained on our general samples taken in this section.

The line of samples was interrupted because a reservoir and a group of small lakes intervened and the road was not opened. It was for this latter reason that the next sample was taken 6 miles further south.

ANALYSIS OF WATER-SOLUBLE, SOIL Laboratory No. 2604

Water-soluble equaled 9.779 percent.

	Percent
Calcic sulfate	15.434
Calcic chlorid	21.325
Calcic nitrate	0.241
Magnesic nitrate	51.159
Potassic nitrate	4.294
Sodic nitrate	3.809
Ferric and Aluminic oxids	0.178
Excess sodic oxide	3.560
	100.000

The next sample No. 2605, was taken as a sample of alkali from a piece of drained land which is also affected by the nitre-trouble. We did not wish to obtain a sample to exhibit the nitre-problem but on the contrary, one to represent the alkali as it occurs in this section. It would have been an easy matter for us to have taken a sample of soil which would have shown only a little, perhaps no alkali.

ANALYSIS OF WHITE ALKALI, Laboratory No. 2605.
Water-soluble 11.403 percent.

	Percent
Calcic sulfate	11.563
Magnesic sulfate	46.958
Potassic sulfate	4.389
Sodic sulfate	13.320
Sodic chlorid	4.065
Sodic nitrate	18.671
Excess sodic oxid	1.034
	100.000

The following sample was collected only a little way south of the preceding and on higher ground which, nevertheless, is wet. Why this place should be wet, I do not clearly see. I could write out an explanation which would be plausible and apparently be consonant with all the facts that we know about the place, but I do not believe that it would be a correct explanation. The fact is that I do not know where the moisture in this spot comes from. I do not know the history of this spot, whether it has been there always or has appeared within the past few years. It is not so bad that the owner has been prevented from trying to crop it. During 1919, it was planted to corn and previous to that to beets. The corn did not grow but weeds had grown to a height of 6 or 7 feet on a great deal of the ground.

ANALYSIS WATER-SOLUBLE, SOIL Laboratory No. 2606
Water-soluble 12.254 percent.

	Percent
Calcic sulfate	41.462
Magnesic sulfate	11.731
Magnesic chlorid	9.182
Magnesic nitrate	10.412
Potassic nitrate	5.239
Sodic nitrate	18.786
Excess sodic oxid	3.188
	100.000

It would seem that this land should be easy to drain, located on the flank of a hill. In fact, land only a few hundred feet from and lower than it is drained. How bad the nitre-problem might be in this land if it were not drained, of course I cannot guess, but it is so bad that a part of this land is now unproductive.

The next sample will give an idea of how bad drained land may be. There was a drain running through this land. The sample of soil was taken partly on one side and partly on the other side of the partly filled drain trench, and is intended to represent the very bad portion of the land. The distance between the last sample given and this is not more than 1200 feet. A portion of the field from which this sample was taken was planted to pop corn in 1919. Some of it grew well and some of it did not. It had no water.

ANALYSIS OF WATER-SOLUBLE, SOIL Laboratory No. 2607

Water-soluble equaled 9.704 percent air-dried soil.

	Percent
Calcic sulfate	28.245
Magnesic sulfate	0.853
Magnesic nitrate	44.930
Sodic nitrate	4.525
Potassic chlorid	3.186
Sodic chlorid	17.799
Excess sodic oxid	0.462
	100.000

The samples were washed till all sulfate disappeared from the wash-water. This means that we washed out any gypsum that may have been present in the soil.

The next sample was virgin soil which was very wet at the time the sample was taken. The location was so unfavorable that I hesitated about taking any sample, but it was either this place or none. The analysis was a troublesome one owing to the presence of much organic matter. The excess of bases, expressed as sodic oxid, is high, still I think that the determinations are correct and that the analysis shows very nearly the actual mixture of salts present in the soil.

ANALYSIS WATER-SOLUBLE, SOIL Laboratory No. 2609

Water soluble equaled 8.71 percent air-dried soil.

	Percent
Calcic sulfate	22.454
Magnesic sulfate	13.225
Magnesic chlorid	18.219
Magnesic nitrate	18.617
Sodic nitrate	19.520
Potassic nitrate	4.056
Excess sodic nitrate	3.909
	100.000

The next sample was taken about 6 miles further south where the conditions were much better, but still not good. The reason for this long jump in this series of samples has been stated in a previous paragraph. The drainage at this point was fairly good and the land under ordinary conditions should be good, productive land, at least much better than it is. The sample of soil was taken to represent the field. Had we wished to gather a sample rich in nitrates this could have been done as it was evident that there were spots where these salts were abundant. The sample represents a strongly alkalized soil rather than a nitre-spot. The land was planted to sugar beets in 1919 but was abandoned because there was a shortage of water.

ANALYSIS WATER-SOLUBLE, SOIL Laboratory No. 2608

Water soluble equaled 6.414 percent of air-dried soil.

	Percent
Calcic sulfate	17.414
Magnesic sulfate	44.688
Potassic sulfate	1.508
Sodic sulfate	21.842
Sodic chlorid	9.622
Sodic nitrate	4.258
Excess sodic oxid	0.578
	100.000

Though this sample represents an alkalized soil rather than a nitre-one we see that there is a little over one-quarter of one percent of nitrates in the soil as the sample was taken. The striking feature of this analysis is the predominance of magnesic sulfate and the relatively small amount of sodic sulfate.

The location where we gathered this sample is nearer to the Poudre river than any other here given and it is almost as rich in magnesic sulfate as the alkali gathered from the bottom lands along the river but is poorer in sodic salts.

These analyses agree in showing the great difference in the composition of these soil extracts from that of ordinary alkalis. These extracts are characterized by subordinate quantities of the sodic salts, particularly of the sulfate, by the presence of large quantities of calcic and magnesic chlorids and nitrates and by notable quantities of potassic oxid.

We have given these analyses of soil extracts, in greater number than was our original intention, to show that the presence of calcic and magnesic chlorids and nitrates was not a peculiarity of the first two samples given, but is characteristic of the whole section here considered.

Two of the samples given are of effloresced alkalis, one of them from drained land and while these samples show that they represent ordinary alkalis, the mixture of salts is not the usual one found, but is rich in magnesic sulfate and also contains some nitrates. The chlorids in these alkalis are low. The drained land from which one of the alkalis was gathered had been tilled in 1919 but the crop was a failure.

CALCIC AND MAGNESIC CHLORIDS

Reference has been made several times to the occurrence of calcic and magnesic chlorids. But the analyses of these soil extracts and alkalis may not impress the reader as justifying the emphasis laid on the subject. In fact, the question may seem to him to have been raised gratuitously, for this reason the following analysis of a sample of surface soil taken southwest of Waverly and about four and a half miles west of Wellington, is given and it will also serve to show the diversity met with in these extracts of soil samples taken within the same neighborhood. The locality at which this sample was taken was higher than the surrounding land and dark, in this case moist, the spot was of considerable size. Other such spots were observed and one other from this neighborhood was submitted to analysis with results similar to those presented in this case.

ANALYSIS WATER-SOLUBLE, SOIL 1 M. W. and ½ M. S. of Waverly, Larimer County, Colorado.

Water soluble equaled 1.96 percent of dried-soil

	Percent
Calcic sulfate	13.264
Calcic chlorid	52.137
Magnesic chlorid	17.687
Potassic chlorid	2.773
Sodic chlorid	11.585
Sodic nitrate	1.045
Sodic silicate	1.507
	100.000

There are large areas in the San Luis Valley where these chlorids, especially calcic chlorid, occur abundantly. The most striking examples of this that I have met with are in a district southwest of Alamosa. The two districts are not to be confounded for they are unlike in every other respect.

The prevalence of magnesic salts in these soil extracts suggests a question regarding their source, i.e., whether there is any unusual amount of them present in the soil itself and not soluble in water. To answer this a soil that had been washed free from chlorids and sulfates was submitted to an ordinary agricultural analysis. The results showed nothing unusual. The carbon dioxid, lime and magnesia were low for our soils. The lime CaO was 1.42 percent and the magnesia 0.336 percent. The alkalis were also relatively low, potassic oxid 0.654 and sodic oxid 0.103 percent.

The origin of this soil is principally the friable sandstone lying above the shale. There is undoubtedly an admixture from other sources but the local rocks are the principal source.

CERTAIN WELL-WATERS

We have previously stated that our attention was first seriously directed to the conditions in this section by the occurrence of nitrates in certain well-waters. This proved to be common enough to make it seem probable that an attempt to find out definitely whether this nitrate in the well-water correlated closely with the occurrences on the surface or not would give positive results. The method adopted was to visit every well in the district and take a sample of the water. It proved to be a somewhat difficult matter to obtain satisfactory data concerning these wells. The present occupants of these ranches often know but little about the places as they may have occupied them but a short time. Many of these places have changed hands or the occupants have changed since we began this work. In locating the wells we have used the names, given in our field notes as the simplest system. We have given the wells along the public roads which gives us definite lines through the section. I do not see that giving the names of the occupants of the ranches can do any harm in this case. Some of them to my certain knowledge have left the places and the names serve no other purpose than to designate where the sample was taken

We have given analyses of some of the soil extracts and we will now give the analyses of a few waters. Two of the waters correspond to soil extracts already given. The third one is an analysis of a water from a drilled well 280 feet deep, sunken in one of the worst places. This analysis follows:

ANALYSIS OF WATER-RESIDUE, Laboratory No. 2370
Total Solids 5328.0 p. p. m.

	Percent
Calcic sulfate	14.584
Magnesic sulfate	5.269
Potassic sulfate	1.271
Sodic sulfate	73.431
Sodic chlorid	4.671
Sodic silicate	0.126
Manganic oxid (br)	0.460
Silicic acid in excess	0.188
	100.000

The following water was obtained from the edge of a beet field. The stand of beets was not perfect but was most remarkably good considering the conditions. The water began to flow into the hole dug to obtain it at a depth of 4 feet and, though the hole was made a little over 5 feet deep, all of the water came in at the 4 foot point. The water-soluble in the surface soil of this field, sample taken between the rows of beets, not in vacant ground, yielded 7.81 percent of its air-dried weight to water. How the seed had germinated and the beets had grown are questions to be answered, but the seed had germinated and the beets were growing well.

ANALYSIS OF RESIDUE FROM GROUND-WATER, Laboratory No. 2372

Total solids in this water were 9808.0 p. p. m.

	Percent
Calcic sulfate	16.139
Magnesic sulfate	41.647
Magnesic chlorid	7.973
Magnesic nitrate	4.519
Potassic nitrate	1.488
Sodic nitrate	24.544
Sodic silicate	0.914
Manganic oxid (br)	0.148
Excess sodic oxid	2.618
	100.000

The 280-foot well was driven a few feet east of the well first dug to furnish water for the owners' cattle and which caused the death of 17 head in a few days. This water was not analyzed. The well was so filled up with dirt and drainage from the corral that it was unfit for analytical purposes. The water from this 280-foot well is used for watering the stock without any bad effects. The people sometimes drink it but state that it physics them. This well is sunk in a Cretaceous shale and is free from nitrates.

The laboratory sample 2372 was taken less than 300 feet south of the corral as a substitute for the first well that was dug. This was the best that we could do in the case though we were at the time satisfied that it was not a dependable sample for this purpose, but it can be considered as an independent sample, which it really is. In the 280-foot well we have no nitrates but an abundance of sulfates, while in the ground-water the total solids carry better than 35 percent of nitrates.

The organic matter in this residue was rather abundant, but can scarcely be appealed to to account for the unusual excess of bases. We must appeal to the possible presence of basic salts or organic matter to account for this excess. We have in many such cases repeated the whole analysis only to obtain the same figures. It is rather common to have a slight excess of bases in analyses of alkalis.

The water represented by our laboratory number 2,371 is locally known as a poisonous water because it frequently causes the death of cattle allowed to drink it, especially if they have been just brought in off the range. This water is very rich in total solids, 9,025.0 p.p.m., of which 36 percent or 3,247 p.p.m. are nitrates. The number of cattle that have died each year has been less than one would expect, judging from the amount and character of the salts held in solution.

ANALYSIS OF WATER-RESIDUE,
Laboratory No. 2371
Well 25 feet deep—Total solids 9025.0 p. p. m.

	Percent
Calcic sulfate	25.410
Magnesic sulfate	26.937
Magnesic carbonate	1.678
Magnesic chlorid	4.496
Magnesic nitrate	21.978
Potassic nitrate	0.558
Sodic nitrate	13.525
Sodic silicate	0.444
Manganic oxid (br)	0.289
Excess sodic oxid	4.863
	100.000

DRINKABILITY OF THESE WATERS

This class of data is really foreign to our present purpose, but the question which is brought up, is one so frequently presented and the results of our observations are so disconcerting that a digression may be tolerated, especially as we have nowhere found any more remarkable instances of the use of water for stock and occasionally for domestic purposes, that judging by all ordinary criteria we would unhesitatingly condemn as wholly unfit for either purpose, than these, and yet neither men nor stock, as a rule, die from their effects. I have a well-water that was used for both purposes, i.e., for both stock and domestic purposes, that carried 3815 p.p.m. of total solids with 51.95 p.p.m. of nitrogen in the form of nitrates. I saw a man take a very large draught of this water; he stated that to him it was an agreeable water; that he drank no other water when on the place. I do not think that there was any bravado in his drinking it. I have seen others drink very bad waters.

In the following instances the animals, horses, were accustomed to the waters used, still I was surprised at the facts and the condition of the animals. I will cite but four instances of the many that I have met. In one case the water carries 12,577.0 p.p.m. total solids with 336.0 p.p.m. of nitrogen as nitrates. Another 10,541.0 p.p.m. total solids with 142.0 p.p.m. of nitrogen as nitrates. On this ranch there is another well which is considered a very good one. Its water carries 3,634.0 p.p.m. total solids and 171.0 p.p.m. of nitrogen as nitrates. Another water carries 10,170.0 p.p.m. total solids and 140.0 p.p.m. of nitrogen as nitrates. This water is pumped from a shallow well into a large tank. The owner is a man of intelligence, and there is an atmosphere of orderliness and thrift about his place. I inquired particularly about the use of this water and its effects. He asserted that his animals after drinking it for a few days learned to prefer it to other water. The animals themselves were sleek, fat, and showed every sign of well-being. In another case a family, man, wife and eight children all rugged, apparently healthy, and happy, was using a well-water that carried 2,244.0 p.p.m. of total solids and 28.0 p.p.m. of nitrogen as nitrates. The sanitary chemist will think that this nitrogen as nitrates does not indicate ordinary pollution. Our thesis is that these nitrates are formed in the surface soil and do not necessarily indicate pollution. Still this last well referred to would shake his confidence in his inference. I believe the inference to be correct, but in this case it is certainly open to serious doubt.

We have a great many inquiries concerning the fitness of water for the use of stock and frequently for domestic uses. Of late years I have practically had no opinion to give, for the tolerance of both man and beast for the salts held in solution and their power to adapt themselves to these waters is so great that assertions based on chemical considerations relative to their fitness or unfitness for either use are of relatively little value. Perhaps they ought to be unfit for use but people who use them suffer no inconvenience and animals become accustomed to waters surprisingly rich in salts, some of which we would usually consider dangerous.

GENERAL SURVEY OF WELL-WATERS

To return to our presentation of the waters of this section. The order in which we shall present these has the object of showing how remarkably rich in nitrates some of these waters are and then to show that these are confined to areas where the surface soil is also rich. We shall endeavor in another place to answer the question whether the nitrates in the surface soil came from the water or whether those in the water came from the soil. This is the crux of the question.

WELLS ON NORTH AND SOUTH ROAD EAST OF WELLINGTON

Our next table gives all accessible wells along a line two miles east of Wellington. We begin at the north end and go south for a little over six miles. This is through the worst portion of the district. It may help the reader a little in visualizing the condition to state that the eastern flank of the valley rises sharply to a height of from 80 to 100 feet only a short distance, from ¾ to perhaps 3 miles, to the east of this road, which is itself almost the eastern limit of the irrigated section.

Beyond this valley to the east there is a large dry-land section. The dip of the rock strata is to the east or away from this valley, so that we would be justified in expecting a leakage out of and not into the valley if there were any in either direction. Reference has already been made to two irrigating ditches located not far to the east of this road and higher than the land.

WELL-WATERS NORTH AND SOUTH ROAD, 2 MILES EAST OF WELLINGTON

Eight miles from north to south.

		Total Solids	Ignition	Chlorin	Nitric Nitrogen
		(parts per million)			
V. R. Kent	16 ft. to water	2,160.0	354.0	30.0	0.8
V. R. Kent	20 ft. to water	4,744.0	660.0	64.0	4.0
Carl Kent	12 ft. to water	4,248.0	686.0	76.0	3.5
O. W. Shields	Well 60' deep, 30' to water	6,266.0	1,000.0	76.0	5.0
Chas. Savel	40 ft. to water	5724.0	1,332.0	92.0	147.0
G. R. Hamilton	160' deep, 100' to water	2,292.0	148.0	140.0	None
Greenwald	Upper well 19 ft. to water	8,998.0	1,934.0	235.0	61.8
Greenwald	Lower well 4 ft. to water	9,786.0	2,056.0	320.0	0.8
C. V. Parker	4 ft. to water	9,212.0	1,700.0	640.0	161.0
C. V. Parker		10,170.0	2,512.0	664.0	140.0
C. V. Parker	Second sample	10,054.0	2,300.0	700.0	134.0
McCandless	Old cistern	7,264.0	1,288.0	428.0	253.0
McCandless	25 ft. deep	12,577.0	3,147.0	——	336.0
McCandless	Second sample	8,413.0	2,512.0	292.0	302.4
Fred Schreiner's	280 ft. deep	4,732.0	144.0	152.0	None
Christ Anst	Old cistern	7,870.0	2,251.0	——	309.0
Christ Anst	Hole near stable	8,725.0	2,517.0	——	296.8
Irrigating Plant		8,992.0	3,404.0	140.0	515.2
Roy Nelson	10 ft. to water	6,702.0	1,265.0	238.0	75.6
G. K. Ruff	400 ft. deep	4,174.0	136.0	90.0	None
G. K. Ruff	Second sample	4,041.0	162.0	81.0	None
G. K. Ruff	Shallow well	7,462.0	1,454.0	76.0	131.6
Fitzpatrick	Shallow well	11,154.0	2,780.0	232.0	610.0
Fitzpatrick	Second sample	11,282.0	3,782.0	228.0	599.2
Victor Akin	S. of Cobb Lake	1,176.0	174.0	68.0	1.0

This road has been chosen as practically the longer axis of the worst part of the whole district. We have given those features in the composition of these waters that may be of interest. The loss on ignition of the dried residue gives a little idea of how much organic matter is present. Of course, in all cases where nitrates are present these are partially or wholly destroyed. The ignition is given for whatever it may be worth. The maximum amount of chlorin found is 700 p.p.m. This was present in a well, 4 feet deep, located in a swale. If this is present as sodic chlorid, ordinary salt, the amount present in a gallon of water would be, in round numbers, 11 grains, which is a very moderate amount for ground waters. The maximum here given is over twice as much as was present in the next water richest in chlorin.

At the northern end of this section we have even in surface wells only small amounts of nitrates. The first 4 wells given show a maximum of 5 p.p.m. of nitric nitrogen which is less than may be present in deep wells that are certainly free from pollution. Water from a depth of 100 feet is free from this form of nitrogen. This well must penetrate the shales for the greater part of its depth, and in the adjoining ranch we find a surface water at 4 feet carrying less than one part per million. The water from a little swale through which an irrigating ditch runs carries 161.0 p.p.m. of nitric nitrogen. The next one to the south is differently situated. Here the surrounding land is black on the surface and has ceased to be productive. The soil is extremely rich in soluble salts, consisting of chlorids and nitrates. The nitrates in these shallow wells are very abundant. 336.0 p.p.m. of nitric nitrogen. The next ground-water south is also rich, 309 and 297 p.p.m. of nitric nitrogen. A well 280 feet deep in an exceedingly bad place yields water of an entirely different character, carrying no nitric nitrogen and the salts present, while abundant, are sulfates instead of chlorids and nitrates. The next water obtained south of this was from a large well dug to furnish water for a small pumping plant to irrigate a piece of land; this was extremely rich, 515 p.p.m. This was followed by one with 75.6 p.p.m. and a surface well with 131.6 p.p.m. This one is close to a very bad nitre-spot. At this place there is also a well 400 feet deep, but in this well-water there is no nitric nitrogen. The next well south of this is a shallow one on the side of a hill and its water is very bad, for which, at this time, we have no explanation. Two or three miles south of this and beyond some small lakes, our series of samples ends and the water of this southernmost well carries only 1.0 p.p.m. of nitric nitrogen.

WELL-WATERS THREE MILES EAST OF WELLINGTON

The country south of this is not well opened up and it was necessary for us to go one mile east to carry our line of wells further south. This statement is made to show the relation between the foregoing and succeeding tables. They together form a continuous line southward.

WELL-WATERS ON NORTH AND SOUTH ROAD, THREE MILES EAST OF WELLINGTON AND EXTENDING FIVE MILES FURTHER SOUTH THAN THE PRECEDING.

		Total Solids	Ignition	Chlorin	Nitric Nitrogen
		(Parts per Million)			
J. H. Martin	6 ft. to water	7,416.0	1,090.0	132.0	None
Robert Green	20 ft. to water	2,358.0	454.0	27.0	1.5
J. H. Nebergall		3,224.0	652.0	233.0	56.5
Chet Giddings	30' to water	652.0	186.0	34.0	18.2
Mrs. Norman		500.0	100.0	11.0	1.2
Arthur Tuttle	700 ft. deep	518.0	29.0	113.0	None
Alex Nelson	180 ft. deep	582.0	139.0	80.0	8.0
H. O. Boller		1,374.0	552.0	147.0	63.0
Geo. Cummings		8,630.0	1,790.0	160.0	57.0
Geo. Cummings	18 ft. to water	1,124.0	214.0	260.0	3.5
John Griffith	30 ft. to water	1,080.0	258.0	64.0	3.0
A. W. Morrish	18' deep Co. Ditch	496.0	132.0	20.0	0.6
Jacob Deering	2 mi. so. Cactus school	1,412.0	114.0	100.0	0.1
A. W. Morrish	Spring W. Cactus school	1,508.0	384.0	36.0	4.0
Mrs. Lewis	14 ft. deep	1,324.0	238.0	22.0	1.5
Seth Lewis	10 ft. to water	1,784.0	326.0	24.0	0.6

This continuation of the line of wells passes into a much better section of country and the waters show it in the less amount of total solids and nitric nitrogen. We were at first surprised to find so much nitric nitrogen in the Nebergall well-water, but a subsequent visit and examination of the soil conditions revealed the fact that the soil carried fairly large amounts of nitric nitrogen, sufficient, in spots, to interfere with vegetation. The same is the case with those marked H. O. Boller and Geo. Cummings. The soil for instance at the Boller place showed in a general sample representing 40 acres, 52.8 p.p.m. nitric nitrogen, whereas the 40 acres immediately north of it showed only 6.1 p.p.m. The Cumming's 40 showed 59.7 p.p.m. and the 40 immediately south showed 9.8. These are as clear instances of the intimate relation between the character of the well-waters and the surface conditions as our data reveal. Others show larger amounts in both soil and ground-waters and involve larger areas but none are clearer than these. These remarks, however, are really in anticipation of data to be presented.

WELL-WATERS ALONG ROAD JUST EAST OF WELLINGTON

The next line of wells runs just east of Wellington and for nearly the same distance between 11 and 12 miles from north to south.

WELL-WATERS, CHEYENNE ROAD,
North to South just East of Wellington

		Total Solids (Parts	Igni-tion per Million)	Chlo-rin	Nitric Nitro-gen
Bally Bunion Ranch	30 ft. deep	1,734.0	506.0	39.0	1.0
R. F. Alcorn	65 ft. deep	10,541.0	2,085.0	....	142.0
R. F. Alcorn	18 ft. deep	3,634.0	1,156.0	....	171.0
R. A. Taylor		858.0	227.0	....	4.5
J. Rue	30 ft. deep	2,442.0	586.0	60.0	37.8
J. Rue	Second sample	2,652.0	585.0	....	32.4
Lincoln Highway Garage		1,378.0	326.0	28.0	14.0
Caillet Bros.	25 ft. deep	3,576.0	886.0	....	4.9
G. F. Strelow	16 ft. to water	2,244.0	460.0	36.0	28.0
J. W. Iddings	12 ft. to water	2,210.0	422.0	49.0	25.2
Jacob Rosenberg		2,428.0	460.0	61.0	54.6
A. Demmel	12 ft. to water	1,910.0	266.0	24.0	0.6
Joe Farrar	15 ft. deep	4,388.0	668.0	40.0	9.8
G. E. Garrett	Spring	2.212.0	318.0	31.0	6.0
G. E. Garrett	8 ft. to water	1,818.0	246.0	32.0	2.5
G. Greenwald	12 ft. to water	2,112.0	244.0	24.0	1.5
G. Greenwald	10 ft. to water	1,982.0	238.0	23.0	1.0
A. L. Seaman	6 ft. to water	2,280.0	262.0	23.0	1.5
Frank Earl	4 ft. to water	2,288.0	192.0	26.0	2.0
Wm. O'Brien	A shallow well	2,558.0	66.0	31.0	3.0

This line of wells is 2 miles west of those previously given at its northern end and 3 miles west of those for 3 or 4 miles at its southern end. We have again a great variation but for the most part it is only moderate compared with the former line.

Nothing has heretofore been given in regard to what uses these well-waters are put. The greater part of them by far is used for watering stock, though a few of them are used for domestic purposes. This applies to all of the wells that have been or shall be given.

On the next road west of Wellington only a few samples were taken because it was clearly evident from our preliminary work, as well as from the results obtained subsequently, that at this time at least nothing would be gained by doing so.

A few samples given below are from the section near Wellington for a distance of about 6 miles. The road itself runs immediately west of the town.

WELL-WATERS, NORTH AND SOUTH ROAD
West of Wellington

		Total Solids (Parts	Igni-tion per Million)	Chlo-rin	Nitric Nitro-gen
Jacob Lesser	26 ft. deep	1,286.0	246.0	18.4	2.0
O. M. Porter	36 ft. deep	2,036.0	408.0	24.0	1.6
A. V. Sinnard	27 ft. deep	2,324.0	446.0	52.0	1.2
L. K. Young		1,886.0	362.0	21.6	0.8
——— Chandler	18 ft. deep	1,707.0	347.0	....	10.4
Pumping Plant	11 ft. to water	1,656.0	281.0	....	6.7

This completes our statements relative to the wells taken on north and south lines. The greatest distance between any portion of these lines from east to west is, I believe, 5 miles and the greatest distance from north to south, rather more than 11 miles.

WELL-WATERS ON EAST AND WEST SECTIONS

We made, in addition to these, one full section and some partial sections from east to west. This gives us a number of wells between the north and south series already given and extends our information relative to the distribution of the nitrates in an east and west direction beyond the territory so far described.

WELL-WATERS, EAST AND WEST SECTION,

Beginning 7 miles east of Wellington and Extending to Waverly, 4 miles West of Wellington

	Total Solids	Ignition	Chlorin	Nitric Nitrogen
	(Parts	per Million)		
S. L. Davis, 7 mi. east of W. Dry-land section, 240 ft. deep	520.0	44.0	10.0	None
G. Relke, 3½ mi. east of Wellington	8,764.0	2,142.0	92.0	191.8
C. V. Parker, 2¼ mi. east of Wellington	10,170.0	2,512.0	664.0	140.0
C. B. Orcutt, 1½ mi. E. of Wellington	2,284.0	482.0	60.0	1.6
J. C. Edwards, 1 mi. E. of Wellington	942.0	218.0	32.0	4.4
.... Stock well in field 3-4 mi. E. of W.	3,052.0	574.0	28.0	19.6
S. K. Young, ½ mi. W. of Wellington	1,886.0	362.0	21.0	0.8
Fred Schneiders, 1½ mi. W. of Wellington	1,230.0	158.0	27.0	1.4
B. H. Bailey, 2 mi. W. of Wellington	9,152.0	2,180.0	34.0	2.0
W. L. Birdsill, 2 mi. W. of Wellington	1,256.0	200.0	26.5	1.6
J. H. Reichert, 4 mi. N. W. of Wellington and ½ mi. S. of Waverly, 40' deep	4,360.0	754.0	57.0	2.0
J. H. Reichert, 24 feet deep	6,328.0	1,378.0	90.0	1.2

We aimed to get these wells in as nearly a straight line as possible. It was necessary, however, to follow the roads and we had to deviate to the south or north according to where the roads were opened. It is very seldom that a ranch house or corral is located away from a public road. The maximum deviation of this line of wells from a straight line across the country is possibly 2 miles to the south.

It will be observed that there is an interval of 3½ miles between the first and second wells given in the preceding table. This is because there are no wells there. The dry-land area comes down into the eastern part of this Wellington district. The table shows that the nitric nitrogen in these waters drops to a normal quantity at a point 1½ miles east of Wellington and that there is but one case in the next 5½ miles in which the nitric nitrogen can be considered as high and that is in a well dug in a field for watering stock and in this it is not very high, 19.6 p.p.m.

Owing to the fact that the roads are not opened in the east and west direction straight through as they are from north to south, we have been compelled to be satisfied with partial sections of the country. The first series of this sort that I shall give is one on a line north of the preceding and the furthest north of any taken. The road is not opened either to the north or east from the Kent place.

WELL-WATERS, ROAD WESTWARD FROM KENT'S PLACE TO NEAR WAVERLY

	Total Solids	Ignition	Chlorin	Nitric Nitrogen
	(Parts per Million)			
V. R. Kent, 16 ft. to water	2,160.0	354.0	30.0	0.8
V. R. Kent, 20 ft. to water	4,744.0	660.0	64.0	4.0
Carl Kent, 12 ft. to water	4,248.0	686.0	76.0	3.5
Well in Sec. 15	....	....	....	56.0
Piatt Place 18 ft. deep *	....	....	....	191.8
B. C. Andrews	2,912.0	474.0	82.0	7.0
J. L. Harms, 50 ft. deep, 34' to W.	2,202.0	330.0	30.0	2.0
J. S. Elder, 85 ft. deep, 9' to W.	518.0	94.0	10.0	0.8
Carl Smith, 12 ft. deep	3,116.0	424.0	68.0	2.4
W. H. Webster	1,428.0	280.0	69.0	5.4

*This well is one mile south of this east and west line and is in lower ground. It is included here because there is no well on our line in this section of land.

If we reject the well on the Piatt place, we see that this line shows in Sec. 15 a decidedly unusual amount of nitric nitrogen, whereas no other well in this line does so. In this work we have at no time attempted to consider, either in water or soils, such amounts of nitric nitrogen as it is usual to find. We have attempted to account only for what may be considered unusual quantities, and that within such wide limits that there can be no question about the amount present being very high. The first 3 wells given in this table are in Sec. 14 and show 0.8, 4.0 and 3.5 p.p.m. of nitric nitrogen. These normally small amounts are, I think, universally considered to be derived from the oxidation of soil nitrogen without consideration of the agency. My thesis is that this applies to the larger quantities as well as to the smaller. There is only one well in Sec. 15 with 56 p.p.m. of nitric nitrogen. In a well just across the line in Sec. 22 we find 191.0 p.p.m. of nitric nitrogen.

The next east and west line of wells that I shall give is a short one, 3½ miles south of our first line and 2 miles south of Wellington. This line begins at the first north and south line given, and extends westward 3½ miles. The ground-waters at the beginning of this line are extremely bad. The land traversed by this line is undulating, but it is not higher, if as high, as the land on the north and south line to the east of it.

WELL-WATERS, EAST AND WEST ROAD 2½ MILES SOUTH OF WELLINGTON

Beginning 2 miles East of Wellington.

	Total Solids	Ignition	Chlorin	Nitric Nitrogen
	(Parts per Million)			
Christ Anst, Old cistern on 1st north and south line	7,870.0	2,251.0	....	309.0
Pumping plant, on 1st N & S line	8,992.0	3,404.0	140.0	515.2
Well near pond	5,012.0	893.0	....	1.4
Second sample	5,238.0	929.0	164.0	1.3
Pond	5,878.0	1,122.0	130.0	None
P. Dalys, 2 miles south and 1 mile east of Wellington	8,265.0	1,358.0	....	9.0
E. Cavins, 2 miles so. of Wellington	3,659.0	680.0	....	7.0

The first two waters given are on the north and south road and near the beginning of this east and west line at the east end. The well at the pond would appear to be pond-water, as the well is only a few feet deep and was full to the top. This well-water was very rich in magnesium salts and we were informed that it physiced the cattle, but both it and the pond-water are poor in nitric nitrogen. The few wells that we found on this road are also low in nitric nitrogen.

WELL-WATER ALONG THE AULT ROAD

The next wells that we have taken on an east and west line are about 8 miles south of the last and are given from west to east, while the preceding ones have been given from east to west. This line of wells begins 6 miles east of Fort Collins on the Ault road and ends north and west of Windsor.

WELL-WATER TAKEN WEST AND EAST ON AULT ROAD

	Total Solids	Ignition	Chlorin	Nitric Nitrogen
	(Parts per Million)			
E. D. Pitcher, 6 mi. east on Ault road	7134.0	1402.0	276.0	23.8
Dr. Atkinson's, 12 ft. to water	8380.0	238.0	22.0	14.0
M. J. Kerr, 12' deep, 4' to water	4340.0	498.0	92.0	28.0
Fred Weiss, Alkali on surface of ground	5874.0	1064.0	240.0	0.3
Frank Wells, 215 feet deep	690.0	100.0	31.0	None
C. C. McElravy	1384.0	38.0	72.0	None
W. E. Poor	978.0	242.0	26.0	6.0

I believe that the well-waters previously given, faithfully represent the distribution of the nitrates in the soil and the underlying rocks of the section. I do not assert that we have sampled every well in this large section of country represented, but none within the limits given have been intentionally omitted.

WELL-WATER IN WAVERLY SECTION

The Waverly section, so far as our work is concerned, is simply a western and northern extension of the Wellington district and some work has been done in this section, because there is a small area in the vicinity of Waverly in which nitrates occur, also because we wanted to know definitely the character of the well-waters in this section, so we have not only carried our east and west lines across to Waverly but have examined a considerable section about Waverly, especially north and west of it.

WELL-WATERS, WAVERLY DISTRICT

	Total Solids	Ignition	Chlorin	Nitric Nitrogen
	(Parts per Million)			
D. C. Harned, 50 ft. deep	5934.0	1542.0	72.0	4.0
Geo. Specht, 9 ft. deep	3316.0	754.0	72.0	1.5
R. F. D. No. 3, Flowing from pipe	2868.0	712.0	110.0	0.8
Ripple Bros, 30 ft. deep on Dry Creek	832.0	196.0	14.0	2.0
P. Aragon, 22 ft. deep	10722.0	2062.0	160.0	0.15
P. Aragon, 90 ft. deep	4496.0	786.0	52.0	None
J. A. Harris, 45 ft. deep	546.0	156.0	34.0	3.0
Roy Randleman, 30 ft. deep	1136.0	274.0	81.0	5.0
Low Christman	4454.0	666.0	44.0	1.5
DRY CREEK, WEST AND SOUTH OF WAVERLY				
Dry Creek at Douglass Dam	4123.0	677.0	....	13.2
W. Dry Creek at road crossing	5771.0	950.0	....	Lost
Dry Creek before entering Douglass Reservoir	3992.0	632.0	....	38.0

This completes the statement of our data on the local waters investigated in connection with this subject.

We have endeavored to so arrange these that the series are easily located in their relative positions and the wells follow consecutively in the direction given for the series. There are a few instances in which the wells may be one-half mile to one side or the other of the line given but there are only four or five of which this is true and to attempt to give these separately would have no object.

It is evident that the rule is, that however rich these waters may be in total solids, the normal water is not rich in nitrates. The presence of these salts is due to local conditions. A second thing which is also clearly and strikingly evident is that none of the deep wells contain any nitric nitrogen and the underlying rocks cannot contain nitrates.

It is entirely out of the question for me to attempt to state the conditions obtaining at these different wells though in some instances a description of the location and surroundings would add somewhat to the value of the data. In the last table for instance, the 22-foot well of P. Aragon is in a depression in otherwise high ground and is remote from his building, in fact it is in a field. The total solids are very high, 10,722.0 p.p.m., with only 0.5 p.p.m. of nitric nitrogen, whereas the shallow well on the Ruff place is similarly located, i.e., on the edge of a depression in high land, really on a hillside, carries 7,462.0 p.p.m. of total solids and 131.6 p.p.m. of nitric nitrogen. These wells may be 7 miles apart on a straight line. Again the well on M. J. Kerr's place was given as 12 feet deep, but when the sample of water was taken, the well was full to the top. This water was being used for irrigating other land. It was evidently seepage water from the immediate vicinity of the well and contained 4,340.0 p.p.m. total solids and 28.0 p.p.m. nitric nitrogen. On the Seth Lewis place a pumping plant had been established for using the seepage water in irrigating adjacent land. The plant raised the water from a depth of 10 feet. The water carried 1,784.0 p.p.m. of total solids and only 0.6 p.p.m. nitric nitrogen. It is evident that there is no general subsurface source from which these nitrates are obtained.

NITRIC NITROGEN IN THE SURFACE SOILS

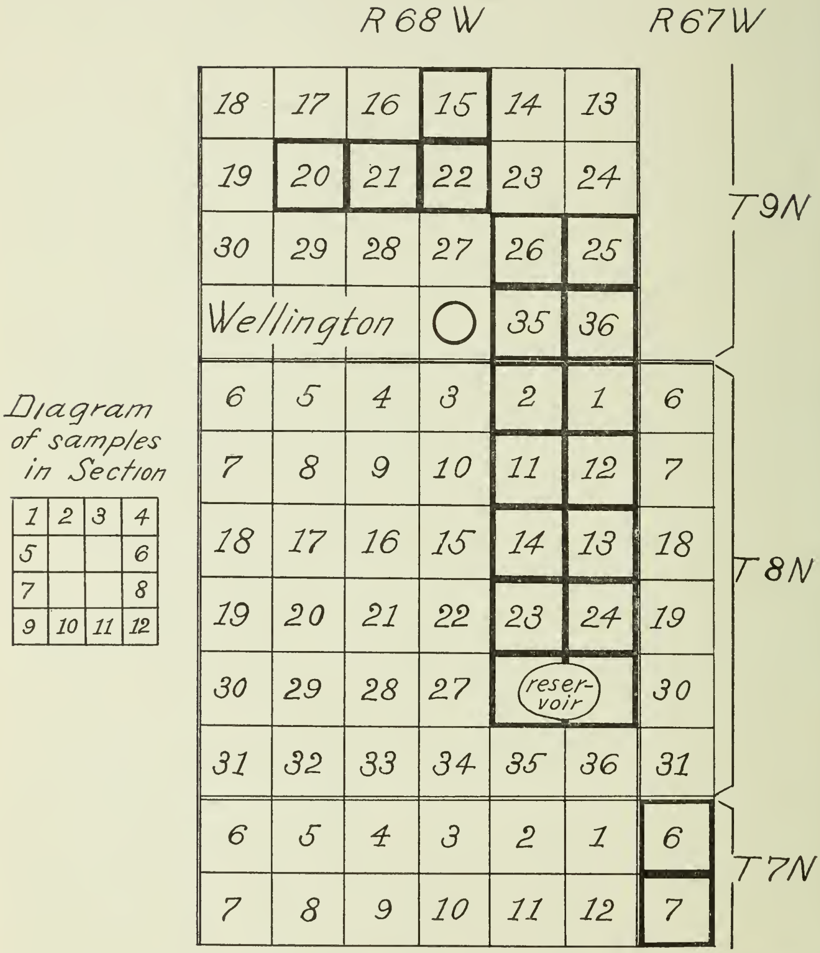
One of our principal objects in this work was to find out whether there was any relation between the quantities of nitric nitrogen in the soils and in the well-waters. This subject has been suggested but not dwelt upon in other bulletins. In Bulletin 186, p. 38, it is stated that the soil there discussed carried in the top 3 inches, 42.3 p.p.m. nitric nitrogen, which decreased rapidly till at 4 feet 9 inches it contained less than 1.0 p.p.m.; the ground-water at this point carried 9788.0 p.p.m., total solids and 4.0 p.p.m. nitric nitrogen. On the page just cited, we find another instance given in which the surface 3 inches of soil carried 52.9 p.p.m. nitric nitrogen and the last section of soil taken above the water-plane carried 57.0 p.p.m. of nitric nitrogen. The ground-water out of this hole carried 18,557.0 p.p.m. total solids and 318.8 p.p.m. nitric nitrogen. The question is put, Why this difference in the distribution of the nitrates, and the answer given is that in one case the nitrates had been washed down into the ground-waters by a previous irrigation, and in the other case they were not washed down, because of the uneven distribution of the water. Again, one of the conclusions formulated in Bulletin 178, p. 95, is, "The ground-waters, unless derived from nitre-areas, are free from nitrates and these nitrates (in the soil) cannot be accounted for by the evaporation of such water from the surface of these areas." These statements referred to small areas, nitre-spots, and the question of immediate association of the nitrates in the soil and the ground-waters was incidental to the object had in view. Our present investigation is on a much broader scale and concerns itself directly with this relation.

For further study of this point we sampled the surface soil of 18 square miles, or sections of land. We sampled 12 of the 16, forty-acre divisions in each section. We united 15 subsamples in each sample. It sometimes happened that a forty was very difficult of access or its location was such that a sample from it would have no object except to simply add one more sample to the statement of results which we tried to avoid.

In this work on the soil nitrates we have at all times felt the need of an acknowledged upper limit above which all amounts of nitric nitrogen may be considered excessive. So far as I can learn, under ordinary humid conditions, 8.0 p.p.m. is a liberal superior limit. I know of no effort to ascertain this limit for semi-arid conditions, though the amount present in such soils may be both higher and more irregular than under humid conditions; still according to our observations, made on very productive land, 8.0 p.p.m. is a fair superior limit to assume. Our good, cultivated soil ranges from 5 to 8.0 p.p.m. unless under crop or immediately after harvest when the nitric nitrogen is materially below these figures, 1 p.p.m. or even less.,

The season of 1919 was an unusually dry one with us. Irrigating water was so short that some of the fields planted to beets remained fallow till late in August or even September when there was moisture enough to germinate the beet seed. It was unfortunate that this season, when we took our soil samples, was so abnormal in this respect. There was no washing out of the surface soil during the season, and in taking our samples we pushed our soil tube down into moist soil if possible. What the effects of such a lack of moisture may have been upon the biological activities going on in the soil, I do not know but I hoped to offset this doubt, at least in part, by taking the sample deep enough to obtain moist soil whenever feasible.

In taking our samples, we began at the northwest corner of the section and numbered our samples as in the accompanying diagram, which also gives the sections sampled and their relative positions.


R 68 W
R 67 W
T 9 N
T 8 N
T 7 N
Wellington
reser-voir
Diagram of samples in Section
1 2 3 4
5 6
7 8
9 10 11 12

The sections sampled are shown in heavy lines in the illustration

The numbers in each section give the location of the 40 acres sampled. If one or more numbers are omitted, it means that the corresponding 40 was not sampled.

NITRIC NITROGEN PARTS PER MILLION, SURFACE SOILS,
Wellington District
Samples taken to Maximum Depth of Six Inches, Range 68 W.

T.	9 N.	Sec. 15
(1)	1	28.5
	2	21.6
	3	20.2
	4	28.5
	5	29.4
	7	9.8
	9	8.9
	10	14.0

T.	9 N.	Sec. 22
(2)	1	15.8
	2	14.0
	3	13.1
	5	13.1
	7	1.9
	8	9.3
	9	25.7
	10	8.6
	11	21.5

T.	9 N.	Sec. 21
(3)	1	7.5
	2	10.8
	3	14.9
	4	4.6
	5	21.5
	6	14.5
	7	52.7
	8	11.7
	9	23.3
	10	36.4
	11	28.9
	12	5.1

T.	9 N.	Sec. 20
	4	7.5
(4)	6	4.2
	8	4.6
	12	2.8

T.	9 N.	Sec. 25
	1	1.4
(5)	2	4.6
	3	25.2
	4	7.5
	5	56.3
	6	7.9
	7	10.8
	8	9.8
	9	19.6
	10	12.1
	11	22.9
	12	9.8

T.	9 N.	Sec. 26
	3	41.1
(6)	4	17.7
	5	26.6
	6	8.4
	7	44.8
	8	7.9
	9	78.3
	10	9.8
	11	17.3
	12	85.4

T.	9 N.	Sec. 36
	1	23.3
	2	7.0
	3	9.3
(7)	4	11.2
	5	5.6
	6	19.7
	7	8.9
	8	9.8
	9	877.3
	10	10.3
	11	12.6
	12	10.3

T.	9 N.	Sec. 35
	1	5.6
	2	30.3
	3	7.5
(8)	4	13.1
	5	11.7
	6	36.9
	7	6.5
	8	81.2
	9	12.1
	10	14.0
	11	7.0
	12	298.7

T.	8 N.	Sec. 2
	1	18.2
	2	12.6
	3	7.9
(9)	4	1092.0
	5	23.8
	6	15.9
	7	61.6
	8	21.0
	9	26.6
	10	53.7
	11	26.6
	12	1941.3

T.	8 N.	Sec. 1
	1	746.6
	2	72.3
(10)	3	29.4
	4	17.3
	5	25.2
	6	11.7
	7	42.5
	9	690.7
	10	10.3

T.	8 N.	Sec. 12
	1	141.4
	2	16.5
(11)	4	25.2
	5	16.3
	6	17.7
	7	28.5
	8	12.6
	9	33.8
	10	29.4
	11	19.6
	12	12.6

T.	8 N.	Sec. 11
	1	44.0
	2	24.3
(12)	3	10.7
	4	1040.7
	5	40.1
	6	15.4
	7	28.9
	8	53.7
	9	14.5
	10	21.0
	11	29.4
	12	43.4

T.	8 N.	Sec. 13
	1	31.6
	2	18.7
	3	28.0
(13)	4	14.5
	5	466.6
	6	12.6
	7	73.3
	9	17.7
	10	27.1

T.	8 N.	Sec. 14
	1	22.4
	2	19.6
	3	20.1
(14)	4	52.3
	5	21.0
	6	858.7
	7	16.5
	8	21.5
	9	9.8
	10	19.6
	11	19.6
	12	28.9

T.	8 N.	Sec. 24
	1	20.1
(15)	2	34.1
	5	462.0
	7	639.3
	9	14.5

T.	8 N.	Sec. 23
	1	9.3
	2	9.8
(16)	3	18.6
	4	9.3
	6	830.7
	8	134.9
	10	14.0
	11	5.1
	12	387.3

R. 67	W. T	7 N. Sec. 6
	1	8.9
	2	7.9
	3	10.8
(17)	4	12.6
	5	15.9
	6	9.8
	7	6.1
	8	8.9
	9	52.8
	10	20.1
	11	14.1
	12	30 8

R. 67	W. T.	7 N. Sec. 7
	1	59.7
	2	60.7
	3	21.0
(18)	4	15.9
	5	9.8
	6	32.7
	7	30.5
	8	27.1
	9	191.3
	10	25.2
	11	17.7
	12	40.6

The land given in this table as having been sampled was supposed to be within the area of high fixation. Our preliminary work referred to had for its object the approximate determination of this question. It will be noticed that in Sec. 20, T. 9 N., R. 68 W., only the eastern side of the section, our numbers 4, 6, 8 and 12 were sampled, and the nitric nitrogen present was found to be 7.5, 4.2, 4.6 and 2.8 p.p.m. This ground is neither high nor low, but a fair representative of average land.

POWER OF THESE SOILS TO FIX NITROGEN

It may appear to the reader, unfamiliar with the data, that we have given in other publications to show that our soils have a very decided capacity for fixing nitrogen under both laboratory and field conditions, and perhaps to the critical reader who is familiar with these data, that in the preceding paragraph we are assuming fixation without proofs, whereas we should produce them. The fact is that we have studied this subject in considerable detail for our Colorado soils. Dr. Sackett, of this Station, has published three bulletins pertaining to the fixing, ammonifying and nitrifying efficiency of our soils. I assume that the presence of nitrates in a soil is proof that the last two processes have been sufficiently vigorous for their production, and that the question of prime importance in my work is the source of the nitrogen contained in them. The main purpose of this bulletin is to ascertain how the nitrates in the well-waters are related to the nitrates in the surface soil; or, put otherwise, to ascertain whether the nitrates in the water have been formed in the soil and have gone into solution in the water, or whether they were first present in the water and were subsequently brought to the surface with it and left when the water was evaporated. In other bulletins the question of the source of the nitrogen, now present as nitrates, has been constantly held in view and repeatedly stated.

Dr. Sackett used 38 different samples of soil, some taken from the surface of nitre-spots, others taken at different depths in the nitre-spots, others taken from the edges of these spots and others taken from unaffected ground outside of these spots. The results of his investigation show that often the surface portion of the nitre areas do not fix nitrogen, while at a depth of 6 inches it still has some fixing power; but at the edges and slightly beyond, the fixing power is much higher than usual. Dr. Sackett's experiments were made by introducing soil extracts into a culture medium, and were strictly controlled laboratory experiments. The results showed conclusively that these soils actually possess the power to take nitrogen from the air, whereas the samples of raw adobe soil tested did not possess this power.

I was not entirely satisfied with the general method of investigation and made some experiments with soils that presented the indications observed in these nitre-areas adding nothing. In one case I kept the moist soil as it was taken from the field at ordinary temperatures, and in other cases I added enough ammonia-free water to make the moisture content of the soil from 15 to 18 percent., and keeping them at a temperature of 27° to 30°C. These experiments gave positive results—quite as pronounced as those obtained by Dr. Sackett in his cultural solutions. Dr. Sackett made a parallel experiment and he also obtained positive results. This procedure removed all questions of manipulation and artificial conditions except the fact that these experiments were made in the laboratory. Some of my experiments were made in the light and some in darkness. This did not appear to make any difference.

FIXATION AND NITRIFICATION UNDER FIELD CONDITIONS

In order to eliminate the questions attaching to the fact that all of these experiments were made in our laboratories and with comparatively small quantities of earth—1200 grains in my experiments—I prepared a sample of 3000 pounds and incubated it out of doors, protecting it from animals, rain and from other accidents. The moisture content was maintained at about 15 percent by addition of ammonia-free water to replace that lost by evaporation. The result at the end of 40 days was a gain of 36 p.p.m. in total nitrogen, and of 15.79 p.p.m. in nitric nitrogen. At the end of this period we applied a dilute solution of calcic nitrate to one portion of the surface; to another portion a dilute solution of sodic nitrate to see if these salts would bring about pigmentation. Both of these salts brought about a decided change from the ordinary light color of the soil to a dark brown, almost black, in a few days. The change was distinct in three days. Later in the season the soil itself showed this change in spots. This change has been observed on irrigating furrows in some portions of this land.

I have expressed elsewhere my conviction that these spots are only exceptional manifestations of a general process that goes on in our soils with unwonted vigor.

It may be urged that all this may be true but it does not show that these spots actually possess an excessive power of fixation in the fields where they are found. In answer to such I present the facts shown by the samples collected by Dr. Sackett, the most of them in my presence and examined by him. It is true that these experiments were strictly laboratory experiments, but the results of laboratory experiments in these lines have yielded results similar to those observed in the field and obtained under field or natural conditions. While the experiments and observations given in the preceding appear to us fully adequate for the establishment of all that we have claimed, we have endeavored to further ascertain the fixing power of samples of soil representing cross-sections of such a nitre-area by simply incubating them, adding only enough ammonia-free distilled water to bring the moisture present up to 15 percent. The area that we have chosen is in the section of country considered in this bulletin. We have had this spot under observation for about three years, during which time it has increased greatly, I would say to at least fifteen times the area that we first observed; and the rate at which it is extending its limits is much more rapid this season than at any time heretofore. Three years ago there was a very small area that was wholly unproductive and none of it was so bad that the owner or lessee did not plant the whole of it. At the present time no attempt is made to plant several acres of it. Four, perhaps five acres of it are now abandoned to such weeds as can tolerate the present conditions. There is no question but that a still larger portion will be abandoned in the spring of 1921, for some of this land which was cultivated last spring, 1920, is at this time entirely devoid of any vegetation. This affected area is on the side of a low hill and is rapidly extending up the hill. This ground is wet, seeped, but where this water comes from is not evident, and the question becomes more perplexing the longer we observe it. There is no apparent source from which this water may come. It is an easy matter to suggest irrigation and leakage from irrigating ditches, (there are two of these perhaps a mile to the east of this place) as the cause of this excessive moisture. This would seem plausible, but the more familiar one becomes with the facts in this section, considering at the same time the contour of the land, the more uncertain one becomes in regard to the validity of such an explanation. The water can scarcely come from any depth, for on the crest of this low hill—perhaps 200 feet from the western margin of this nitre-area—there is a deep well, 400 feet to water, which carries 4,170 p.p.m. total solids but no nitric nitrogen. Whereas, the worst portion of this area carries nitric nitrogen equivalent to sodic nitrate equal to 2.5 percent or rather more of the air-dried soil. Some of the land at the foot of this hill and west of the road is drained, but its condition is very bad.

FIXATION IN A NITRE AREA

In order to ascertain how vigorous a fixation the aforementioned area might manifest, five samples were taken and incubated for 30 days at 27°C. Twelve hundred grams of air-dried soil were taken and enough ammonia-free distilled water added to bring the moisture content up to about 15.0 percent. The five samples represent a section from north to south across the shorter diameter of the area. Sample 1, apparently normal soil, was taken in the field 60 feet north of the area; sample 2 was taken 30 feet north of what we considered the northern margin of the area; sample 3 at the northern margin of the area; sample 4 at the southern margin, and sample 5 still further south in an alfalfa field on the flank of a portion of this same hill.

	Before Incubation		**After 30 Days**		**After 40 Days**	
Sample	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen
1	0.1054	0.00175	0.1163	0.00458	0.1045	0.00459
2	0.1018	0.00197	0.1031	0.00432	0.1029	0.00420
3	0.2570	0.13615	0.2574	0.1477	0.2590	0.1402
4	0.3395	0.2068	0.3620	0.2261	0.3620	0.2023
5	0.1315	0.0034	0.1282	0.0070	0.1284	0.0135

The worst portion of this area is not included in these samples. It was very rich in nitric nitrogen, carrying 4,500 p. p. m.

These determinations were made in triplicate and some of them checked by repeated determinations. One of these samples shows a decided increase in the total nitrogen, 229 p.p.m.; three of them show small increases, 4.13 and 20 p.p.m. respectively, and one of them shows an actual regression in the amount of total nitrogen present. Sample 1 shows an increase of 105 p.p.m. in the total nitrogen in 30 days, but in the next ten days it seems to have lost rapidly. Sample 4 shows a gain of 225 p.p.m. in 30 days and maintains it during the next 10 days. All of the samples show a decided increase in the amount of nitric nitrogen present for the 30-day period, but some of them show a falling off for the subsequent 10-day period. The amounts of total and nitric nitrogen in the land just outside of, and at the edge of the area, differ very markedly, and the ratio of the nitric nitrogen to the total increases from about 20 percent., which is very high, to more than 50 percent., and in only one instance has this ratio decreased during the incubation.

We were not satisfied with these samples, and besides we encountered unexpected difficulties in these determinations; therefore, we took a second series of samples. The two series of samples differ in important respects. The first series was taken in March and the second in September. It was impossible to sample the same section of the area for the second series; besides the area had increased very materially during this interval. It was practically a new part of the area that we had to sample for the second series, and we increased the number of samples to 10 instead of 5.

We first took 6 samples as nearly in a straight line as we could, from north to south as was previously done, but a preliminary test of these samples showed that there was an excessive quantity of nitric nitrogen in our northern-most sample, a condition that we suspected from the appearance of the soil in the field. In order to get beyond the affected area, we subsequently took two samples in an east and west line, beginning next to the bad area; but a quantitative test showed that our western-most sample, taken well up on the hill, contained more nitric nitrogen than an ordinary soil contains, the determination showing 129.0 p.p.m. It, therefore, became necessary to take further samples to avoid, if possible, initial, excessive quantities of nitric nitrogen. We accordingly took two other samples on a northward extension of our north and south line. This land had been in crops, oats and corn, during the season, but these had been cut before our samples were taken. The appearance of the soil, the stubble and the statement of the lessee agreed in indicating that these crops had been satisfactory. The object of these tests was to ascertain the fixing power of this soil outside of, at the edges of, and within the nitre area. That it has a sufficient nitrifying power is assumed, and its determination and statement are incidental. The samples were taken to a depth of three inches. The results obtained were as follows:

RESULTS OBTAINED BY INCUBATING SAMPLES OF SOIL FROM A CROSS-SECTION OF A NITRE-SPOT.

	Before Incubation		After 30 days' Incubation		After 40 days' Incubation	
	Percent Total Nitrogen	Percent Nitric Nitrogen	Percent Total Nitrogen	Percent Nitric Nitrogen	Percent Total Nitrogen	Percent Nitric Nitrogen
1	0.1320	0.0031	0.1435	0.0075	0.1770	0.0069
2	0.1345	0.0036	0.1508	0.0065	0.1870	0.0063
3	0.1340	0.0050	0.1300	0.0111	0.1860	0.0135
4	0.1320	0.0061	0.1560	0.0149	0.1950	0.0135
5	0.3040	0.1950	0.3020	0.1970	0.3530	0.1840
6	0.3970	0.2930	0.3940	0.2770	0.4130	0.2340
7	0.1335	0.0258	0.1580	0.0270	0.1920	0.0258
8	0.1035	0.0145	0.1295	0.0096	0.1605	0.0059
9	0.1340	0.0193	0.1520	0.0159	0.1840	0.0145
10	0.1245	0.0129	0.1525	0.0230	0.1750	0.0196

These samples, from 1 to 8 inclusive, are numbered regularly from north to south across the nitre-area. The area represented by Nos. 5 and 6 was entirely devoid of any vegetation. Nos. 1, 2, 3 and 4 were all supposed to be outside of the nitre-area. No. 1 was 150 feet, No. 2, 100 feet, No. 3, 60 feet north and outside of the nitre-area, while No. 4 extended up to within a few feet of the edge of the area. No. 7 was from a beet field at the south edge of the area. The presence of nitrates was strongly indicated by the color and the condition of the soil, also by the color and growth of the beets. No. 8 was also from this beet field, but neither the soil nor the beets indicated any excessive supply of nitrogen. Nos. 9 and 10 represent 60 feet or more in a westwardly direction, almost to the top of the hill at this point. The land outside of the area shows, in round numbers, a fixation of 500 p.p.m. in 40 days; at the edges, 610 p.p.m. and within the area the minimum of 160 p.p.m. Expressed in a different way, this soil has a high power to fix nitrogen, one sufficient to form 1,350 pounds of proteids in the surface three inches of the soil each 30 days, but near the edge of the nitre-area this amount rises to 2,745 pounds in the same period; while in the interior of the area, where the nitrates and other salts are very abundant, the amount of proteids formed falls to 720 pounds in 30 days, and may fall to zero, as we have elsewhere stated. The nitrifying power is also high. The deportment of these samples, which can be taken as representative of all of these areas in this section, shows independently of the results obtained in our general survey, that the nitrates present in them are actually formed in the soil of these areas. The amount of nitrogen fixed in our experiment is sufficient to furnish a great deal of nitrate if it were all nitrified, and we observe an increase of from 100 to 170 percent in the amount of nitric nitrogen during the period of incubation.

CORRELATION OF NITRIC NITROGEN IN WATERS AND SOIL

We have attempted to give the correlation of the nitric nitrogen in the soil and water in a specific case in the following table. While it is not wholly satisfactory, it shows that in this detailed way there is a close relation between the nitrates in the soil and in the water. Here the area is not large, but it meets the objection that the nitrates have been brought into the area by the water, and hence they should correlate in a general way, and the richness of the surface soil would have to be accounted for by concentration at the surface, due to evaporation. These suggestions involve questions that would have to be proven by the objectors before much importance can be attached to them. Our aim is to prove in a bigger way that such suggestions have no force. We are aware that the amount of nitric nitrogen found in different sets of samples, taken from any given 40 acres of land, will vary and may vary greatly according as the land is occupied by growing plants or is fallow. Further, these samples will vary with the amount of moisture in the soil, a slight depression in the surface, only enough to cause a difference in the moisture, will have a decided influence upon the amount of nitric nitrogen present. Still it is a fact that the territory surrounding the land which we have sampled is average land, containing an average amount of nitric nitrogen and a large territory to the west and south of Wellington is cultivated and exceedingly fine, productive land.

NITRIC NITROGEN IN SOIL IN EACH 40 ACRES ON EITHER SIDE OF NORTH AND SOUTH ROAD, 2 MILES EAST OF WELLINGTON, BEGINNING 1½ MILE NORTH OF AND EXTENDING 4½ MILES SOUTH OF WELLINGTON, TOGETHER WITH THE WELLS ON THE SAME ROAD.

Nitric Nitrogen, p. p. m. SOIL			Nitric Nitrogen, p. p. m. WELLS		
West	East		West	East	
7.9	10.8		0.8		
8.4	56.3			134.	
7.7	1.4				
85.4	19.6			101	
				50	
13.1	23.3				
36.9	5.6				
81.2	8.9				
298.7	877.3)	(336.0			
	)	(302.0			
1092.0	746.6	253.0			
15.9	25.2				
21.0	42.5				
1941.3	690.7				
1040.7	141.4			(309.4)	
	)			(296.8)	Well 280 ft. deep, none
15.4	16.3				
53.7	28.5				
43.4	23.8	515.2			
52.3	31.7				
858.7	466.6			131.6	Well 400 ft. deep, none
21.5	73.3	610.0			
28.9	17.7	599.0			
9.3	20.1				
830.7	462.0				
134.9	639.0				
387.3	14.5				

The bigger features of this case present these facts. The higher lands surrounding the area in question are not unusually rich in nitric nitrogen, that is, they carry less than 8.0 p.p.m., which is not sufficient to account for any accumulation of it. The rainfall is less than 15 inches and cannot effect much washing. Even with irrigation, this amount of nitric nitrogen is not sufficient to show any effect upon the nitric nitrogen contained in the ground-waters. This is shown in all of the tables giving the nitric nitrogen in well-waters, especially in those from the Waverly district or on the Cheyenne Road south of Jacob Rosenberg's. The drainage into the bad area is not great and if there were a sufficient amount of it to justify consideration, the content of neither the soil nor the ground-waters of the surrounding lands in nitric nitrogen would account for the amounts found, nor could any possible accumulation be effected in the places where we find them.

NITRATES ARE NOT DERIVED FROM ANY DEEP SEATED SOURCE

Another conceivable source of these nitrates is the waters below the surface. While water is found at various depths at different places the country is not blessed with an abundance of springs which might bring the nitrates to the surface from a subterranean source either deep seated or shallow. Our survey of the well-waters answers this question fully. The waters from deep wells are free from nitric nitrogen. The greatest depths at which water carrying nitric nitrogen has been obtained is 65 feet and this is very unusual. On the other hand I have given instances in preceding publications to show that the nitric nitrogen in ground-waters was derived from the surface and not from below—in one case, water at a depth of 6 feet was heavily charged with nitric nitrogen, while water from the same land, but obtained at a depth of 16 feet, carried none. This was not only in the same land but in the same part of that land, in fact from the same hole at different depths. In this case the water from a depth of 6 feet carried 14,230 p.p.m. of total solids of which 3.0 percent or 426.9 p.p.m. was sodic nitrate. The water from the depth of 16 feet and out of the underlying shale carried 22,100.00 p.p.m. total solids and no nitric nitrogen. (Bulletin 178, p. 64.) The table just given shows a sample of ground-water and one from a 280-foot well. This well was started in this bad ground and enters the shale a short way from the surface. The ground water (2 samples) carries 7,870 and 8,725 p.p.m. total solids with 309.0 and 296.8 p.p.m. nitric nitrogen. The well-water carries 4,732 p.p.m. total solids and no nitric nitrogen. In another case shown by the same table we have in the ground-water 7,462. p.p.m. total solids with 131.6 p.p.m. of nitric nitrogen and in the well-water 4,044.0 p.p.m. total solids with no nitric nitrogen. This well is 400 feet deep and about 500 feet from the surface well. The deepest well that we found in this section was 700 feet deep; the water carried 518 p.p.m. total solids and no nitric nitrogen. Another well carried 10,541.0 p.p.m. total solids and 142.0 p.p.m. nitric nitrogen. A well just west of this and at a lower level carries 2,036 p.p.m. total solids and 1.6 p.p.m. nitric nitrogen. In this case again there is not a general deep seated source of this nitrate and it must be an accumulation from the surface though an unusual one.

We find then that no water from any deep well carries nitric nitrogen and a deep seated source of these nitrates is disproven by this evidence. To the best of my knowledge this is in harmony with the results obtained by others in the examination of deep well-waters. I think that the depth of 65 feet previously given is an unusual depth from which to obtain nitrates. In this case it is not a question of a few parts per million but of many.

NITRATES HIGH IN WELL-WATERS ONLY WHEN NITRATES ARE HIGH IN SURFACE SOIL

If we consider the various smaller areas within this section we will find the same facts obtaining. I have brought together in the preceding table the nitric nitrogen in the soils and well-waters in such a manner that the results stand opposite to each other.

Where the nitrates are high in the surface soil the well-waters are also high. I have previously made mention of the fact that one may ask,—does the nitric nitrogen in the water come from the soil or contrariwise; does the nitric nitrogen in the soil come from the water? We have elsewhere shown that our ground-waters carry no nitric nitrogen except they come from beneath a nitre-area and have given one instance in which a ground-water was very rich in nitric nitrogen, whereas water obtained at a depth only 10 feet below this ground-water contained no nitric nitrogen. The latter water evidently could not be the source of the nitrates in the ground-water.

There is another possible explanation, to-wit: that this ground-water represents the leaching out of a large surrounding territory. This phase of the question was considered at length and in detail for a case in which the nitrates occurred in large quantities and we could find no basis whatever to support this suggestion.

Another source has been suggested, i.e., the waters used for irrigating the land. These waters have been examined very many times in the past and we have uniformly found only small amounts of nitric nitrogen usually less than 0.5 p.p.m. The maximum that I have record of is 1.5 p.p.m. for Arkansas River water taken at Rocky Ford which was a return water. If the waters used for irrigating these lands were the source of the nitrates, their occurrence should be more general and in all lands irrigated with this water, this is not the case.

In describing the part of the Wellington district that is particularly discussed in this bulletin, I stated that the depressions were small, some of them not more than a mile wide, and separated from the neighboring depression by a ridge so that drainage either into or out of them is difficult. The collecting area for such a basin is very limited and each such basin is a case by itself but is similar to the others. In such basins the shallow wells yield bad water. It was such a well that caused the death of the 17 head of cattle. At this place a deep well, 280 feet deep, yields water free from nitrates. It is not every depression within this area that yields nitrates. A little to the south, half a mile, and about 1 mile west, we find a place with water on the surface of the ground (I do not know that this is true the year round) with a well at the edge of this pond. Neither the well nor pond-water shows the presence of nitrates. The well-water was said to be bad for stock.

Perhaps 3 wells in Secs. 6 and 7, T. 7 N. R. 67 W. show the relation of the characters of the water and the surface soil better than these in which the nitrates are so abundant. In these cases the soil is richer in nitric nitrogen than normal, 52.0, 59.0, 60.0 and 191.0 p.p.m. and the well waters at these places carry 56.5, 63.0 and 57.4 p.p.m. of nitric nitrogen, whereas the neighboring wells carry 1.5, 1.2, 3.5, 3.0, 0.6 p.p.m. and two deep wells in the next section carry none and 8.0 p.p.m., respectively.

I know that objection may be made to the adequacy of this proof but it appears to me that no successful denial can be made of the conclusion that the surface soil is the source from which these nitrates are derived, as the wells are from 18 to 25 feet deep.

FOUR EXCEPTIONAL WELLS

I have met with but 4 cases in which I had any doubt at all about the nitrates having been derived from the surface soil, above and surrounding them. These four were widely separated from one another; two of them were in the Arkansas Valley and two in the area discussed in this bulletin.

The two instances in the Arkansas Valley were called to my attention by the correspondence of the owners. I went to see these wells but one of them had been filled up. The other well was 27 feet deep. The water carrying zone was one foot thick and began at a depth of 23 feet. No water came in below the 24th foot. This was in a dry-land section and there was no canal or other water very near to it. The last time that I visited this well it was dry. There was no other water found on this ranch, though one well was dug to a depth of 28 feet and another to a depth of 50 feet, which developed a pocket of good water that was soon exhausted. The nitrates present in this water, calculated as sodic nitrate, amounted to 5,440.0 p.p.m. I find that in writing of this in 1911, (Bulletin 178, p. 75.) I said "The source of the nitrates contained in this water is unquestionably, I think, the higher lying surface soil to the north of this place. Why the water should be confined, as it apparently is, to this particular area is not evident". I have quite recently endeavored to find other instances like this in that section but have failed. Deeper wells were sunk at this place without obtaining water and wells on neighboring ranches yielded good water.

These four cases that have come under my own observation are mentioned as possible exceptions to the claim that the nitrates in the waters of shallow wells come from the surface soil.

CONCERNING THE SOURCE OF THE NITROGEN IN THESE NITRATES

For my views as to the source of the nitrogen and the process by which it is converted into nitrates, reference may be had to Bulletins 155 and 178 under the title "The Fixation of Nitrogen in Colorado Soils", also Bulletin 217, p. 5 **et seq.** and Bulletin 183, p. 116.

Briefly stated, the salient features of this question are as follows: These spots or nitre-areas are richer in nitrogen than ordinary soil; they are also very much richer in nitric nitrogen or corresponding nitrates than ordinary soil. Further, the ratio of nitric nitrogen to the total nitrogen is always high. It is always assumed that the conversion of proteid nitrogen into nitric nitrogen is a process so well established, so universal and so generally accepted that it is unnecessary to so much as make mention of it. The question to be answered is, where does the nitrogen, be it in the form of proteid or of nitric nitrogen, come from.

My view is that it is derived from the atmosphere through the agency of living organisms that are capable of appropriating the atmospheric nitrogen to build up their nitrogenous components. As the azotobacter are capable of an independent existence and of accomplishing this, they were the first organisms to suggest themselves as the agency.

It does not follow that other organisms may not take part in this process; in fact, it seems very certain that there are other organisms, either alone or in association, which may effect this fixation as well as the recognized azotobacter. I have previously explained this process as one carried out by bacterial agencies. It is much better and probably more accurate to use the term biological activities which I use to include mixed floras, as well as those which are at the same time capable of fixing nitrogen and of an independent existence.

SUMMARY

The study of this setion leads us to the recognition of a rather large area south and east of Wellington throughout which nitrates occur abundantly in the surface soil.

That there is another smaller, and, at the present time a less important occurrence, in the Dry Creek section south and west of Waverly.

That the waters of shallow wells and the surface soils are closely related in regard to the nitric nitrogen present in them.

That there is not any abnormally large amount of nitric nitrogen in the soil of the district outside of the nitre-area.

That shallow wells outside of these areas do not contain any abnormal quantities of nitric nitrogen.

That the waters from deep wells, even when either sunk through or adjacent to areas very rich in nitric nitrogen, are free from it and would not, even if they should find egress at this or any other point, bring nitric nitrogen to the surface.

That the composition of the salts held in solution in the deep well-waters differs from that of those held in the ground-waters; the former holds essentially sulfates of soda and lime, while the latter carry nitrates and sulfates of magnesia and soda, with some calcic sulfate.

That the extracts of soil samples taken from these areas are characterized by the presence of much magnesia, high nitric acid, low sulfuric acid, low lime and low soda.

That the amount of potash in these extracts is uniformly high, from 0.7 to upwards of 2.0 percent of the total soluble portion.

That the ground-waters and the soluble portion of the soil, even when associated with effloresced "white alkali" are very rich in magnesic salts.

That the ground-waters derive their nitrates from the soil and the amount is determined by local conditions.

That calcic and magnesic chlorids occur in considerable abundance in some of the soil extracts, but the explanation of this fact is not apparent.

That the surface soil, especially at the edges of these nitre-areas, has a very high capacity for fixing nitrogen.

That the facts that we have been able to ascertain support the view that the nitrates occurring in this area have no source outside of the area and on the surface. Further, that there is no source beneath the area from which they are derived. Within this area the nitrates are formed **in situ**, a view that I have elsewhere maintained for other sections.

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Bulletin 259 April, 1921

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Colorado Plant Diseases

BY

Julian G. Leach

Assistant in Botany

1945

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1921

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Colorado Plant Diseases

By JULIAN G. LEACH
Assistant in Botany

INTRODUCTION

Few people realize the extent of the loss caused by plant diseases. The casual observer is often unaware of the presence of disease in his fields. Furthermore, when the disease is known to be present the damage is usually underestimated. The United States Department of Agriculture, as a result of a nation-wide survey, estimated that in 1917 there was a loss of 64,344,000 bushels of wheat due to disease. This loss amounted to nearly ten per cent of our total production for the year. In the same year, which was not an especially serious one, the potato crop was reduced 117,174,000 bushels, or a little more than one-fourth of the entire crop. The corn crop suffered a loss of 175,344,000 bushels. Other farm crops were reduced in similar proportions. In Colorado alone the injury to farm crops from plant diseases amounted to nearly $10,000,000.

These figures are sufficient to convince anyone that every person who is in any way interested in crop production should be able to recognize the diseases that cause such an enormous loss and should know how to successfully combat them.

The purpose of this bulletin is to furnish to the people of Colorado such information as will enable them to understand the nature of plant diseases, to recognize them as they occur in the field, garden or orchard, and to apply the best and most effective control measures.

For convenience, the bulletin has been arranged in three parts. Part I gives, in simple, non-technical language, something of the nature of plant diseases and the agencies which produce them. Part II deals with specific diseases of Colorado crop plants. The crops have been arranged alphabetically and the diseases of each are treated in order of their relative importance. A few diseases are described which do not occur in Colorado, but on account of their serious nature and the importance of keeping them out of the state it has been thought advisable to include them at this time. Part III treats of the general principles of plant disease control and gives rules and formulae for the preparation and application of standard sprays and solutions for seed treatment.

A bibliography has been added for the convenience of those who may desire further information concerning the diseases described.

PART I

THE NATURE OF PLANT DISEASES

Every plant disease has a cause, although the cause may, in some cases, be rather obscure. The cause may be merely some unfavorable condition of environment such as too much or too little water, excessive heat or cold, or the lack of some essential element in the soil. Most of the important plant diseases, however, are caused by very small microscopic plants which live upon and draw all their food from the diseased plant. These small microscopic plants live on the large crop plants just as the crop plants live on the soil in which we plant them. They live on the larger crop plants and draw their food from them just as the well known mistletoe lives on and draws its food from the trees on which it lives. They also produce "seed" or spores, similar to the seed of higher plants, which, when they fall upon the proper plant, under the proper conditions, will germinate and penetrate the leaf, stem or root of the plant just as the seed of a higher plant penetrates the soil.

Mistletoe Growing on a Western Yellow Pine

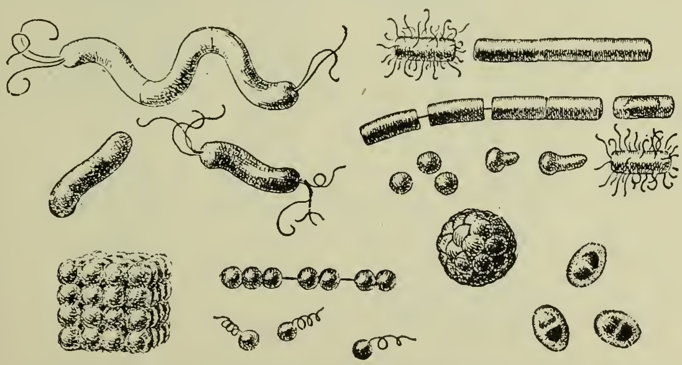
A plant living upon another in this manner is known as a parasite. The plant on which the parasite lives is said to be diseased. A disease caused by such a parasite is known as a parasitic disease.

Diseases, then, can be divided into three general classes on a basis of their cause. Those diseases caused by one organism living upon another are put in one group and called **parasitic diseases.** Those caused by unfavorable conditions of environment such as heat, moisture and food are placed in a second group and called **physiological or non-parasitic diseases.** As mentioned above there are a few diseases the causes of which are not understood. These constitute a third group, which may be called **diseases of uncertain cause.**

PARASITIC DISEASES

The parasites which live upon the crop plants are very numerous and of many kinds. There are almost as many kinds of parasites as there are plants on which they live. For convenience in study, those parasites which cause plant diseases are divided into five groups, those which are very much alike being placed in the same group. These groups have been named as follows: 1. Bacteria, 2. Slime molds, 3. Fungi, 4. Flowering plants, 5. Insects and other animals.

Bacteria—Bacteria are sometimes spoken of as germs or microbes. They are, however, very small plants, extremely simple in form and structure. They are indeed the smallest and simplest plants known. In size they range from 1/50,000 to 1/10,000 of an inch in diameter. In shape they may be spherical (ball shaped), cylindrical (rod shaped) or spiral (shaped like a corkscrew). Those that cause plant diseases are mostly rod shaped. The other kind live on dead organic matter or as parasites on animals.



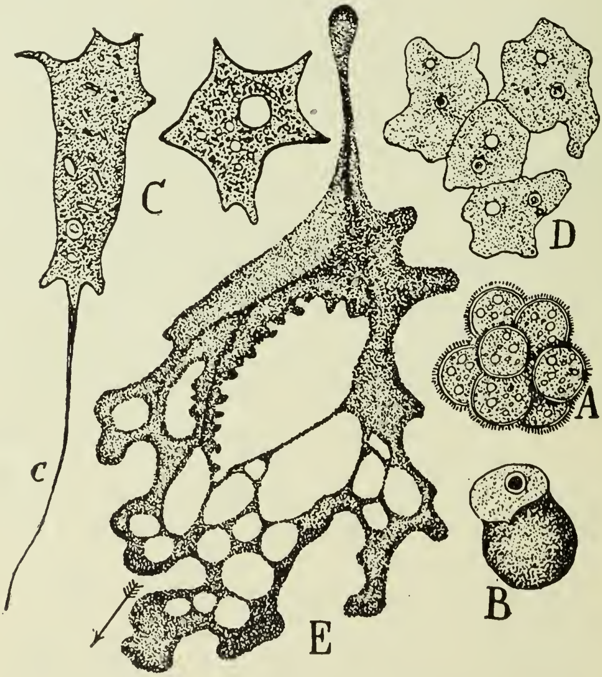
Some common forms of bacteria, greatly magnified. From Transeau Science of Plant Life. Copyright 1919, by World Book Co., Yonkers-on-Hudson, New York

Some forms of bacteria are able to move about in water and plant juices by means of little hair-like attachments to their body. These hair-like attachments, known as **flagella,** move rapidly back and forth, propelling the bacterium through the liquid. These forms which are capable of motion are the ones which commonly cause plant diseases. Other forms do not have the power of motion and depend on outside agencies such as wind and moving water to carry them from place to place.

Bacteria gain entrance into the leaves, stems and roots of plants by means of breathing pores or injuries. After gaining entrance the bacteria live on the substance of the plant, either killing it (or parts of it) or causing it to make abnormal growth, thus bringing about a diseased condition.

Fire blight of apples and pears, stem blight of alfalfa, wilt of squashes and melons, black rot of cabbage and crown gall of many plants are a few of the serious diseases caused by bacteria.

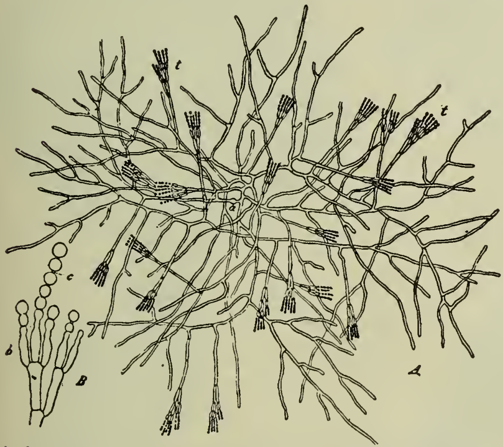
Slime Molds—Another group of plants which sometimes cause plant diseases are the slime molds (Myxomycetes). They are called



The life history of a typical slime mold. A—A group of amebae fusing to form a plasmodium. E—A plasmodium. (After Curtis, Henry Holt & Company.)

slime molds because of their slimy appearance in one stage of their life history. Slime molds are also very small and primitive plants although much larger than bacteria. At one stage in their development they have the appearance of a slimy particle of jelly-like substance. This structure is known as a plasmodium. A plasmodium has the ability to move about by a peculiar rolling or flowing movement. When it grows old or meets with unfavorable conditions the plasmodium breaks up into numerous spores which can live over unfavorable conditions. When conditions are again favorable the spores germinate to form bodies (**amoebae**) similar to a plasmodium but much smaller. A plasmodium is formed by a number of these amoebae uniting with one another to form a single body.

Only a few of the slime molds cause plant diseases. Most of the forms live on dead and decaying wood. A few forms, however, may gain entrance into the roots or stems of plants and cause a disease. Powdery scab of potatoes and club root of cabbage are the most important diseases caused by slime molds.



A fungus. A—The mycelium of a bread-mold fungus. (Penicillium) a—The original spore from which the mycelium grew. t—A tuft of spores. B—A more highly magnified spore tuft, showing how the spores are borne. (After Zopf.)

Fungi — The fungi make up a large and varied group of plants and are responsible for about 90% of the common plant diseases. In addition to those fungi which cause plant diseases there are thousands of other kinds which spend their entire life on decaying plants and other dead organic matter.

Most plants manufacture their own carbohydrate or starchy food by means of the green coloring matter (**chlorophyll**) found in their leaves. The fungi, however, as well as the bacteria and slime molds do not have green coloring matter and consequently can not make their own food. Since these organisms require carbohydrates for their nourishment it is evident that they must obtain it from some source in an already manufactured condition.

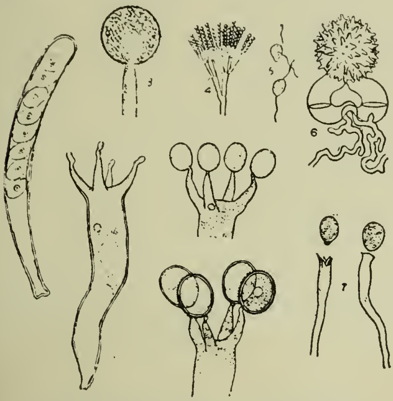
Some fungi obtain their nourishment from decaying organic matter, while others obtain it directly from the living chlorophyll bearing plants. It is the latter kind, of course, which cause plant diseases. Fungi which obtain their food from dead organic matter are known as **saprophytes**. Those which obtain their food from living plants are known as **parasites**.

Fungi differ from higher plants also in that they do not have leaves, stems or roots. The body of a fungus consists chiefly of a fine, branched, thread-like structure, known as a **mycelium**. This branched, thread-like mycelium is usually more or less interwoven to form a cottony or woolly mass such as is seen in the common bread mold fungus. In some kinds of fungi this mycelium may be so crowded together so as to form a solid mass. The common mushrooms are examples of this type of fungus.

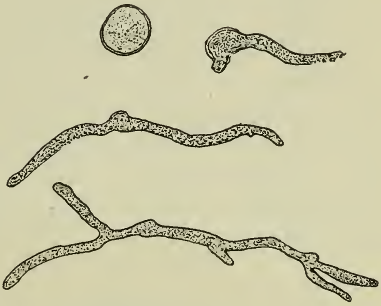
A common mushroom. (Original, bulletin 201, by Longyear.)

All fungi reproduce by means of very small seed-like bodies known as **spores**. These spores may vary greatly in size and structure but they all have the power of germinating and forming a new plant. Spores also vary greatly in the way they are produced. The form of the spores and the way in which they are produced are important as means of distinguishing the different kinds of fungi.

In order to thoroughly understand the nature of a plant disease it is necessary to know something of the nature of the organism that produces it. It is, therefore, important that we learn something of the nature of fungi before we take up the study of the diseases which they produce.



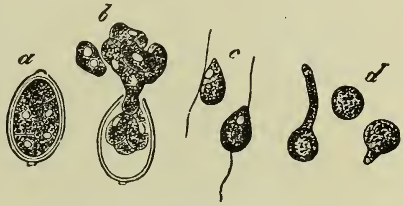
Some different kind of fungous spores. (After de Bary, Sachs and Brefield.)



A germinating fungous spore.

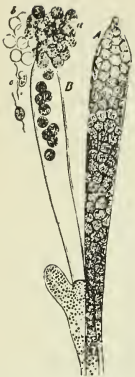
Fungi, for convenience of study, are divided into four large groups, the members of each group having a number of important characteristics in common. These groups are known by the following names: 1. Phycomycetes, 2. Ascomycetes, 3. Basidiomycetes, 4. Fungi Imperfecti.

The Phycomycetes include the simplest and most poorly developed forms of fungi. In some species hardly any mycelium is developed and the plant is extremely simple in structure. The mycelium never has any cross walls but consists of a continuous tube filled with a jelly-like substance (protoplasm). The mycelium of all other groups is divided into short cells by means of cross walls.



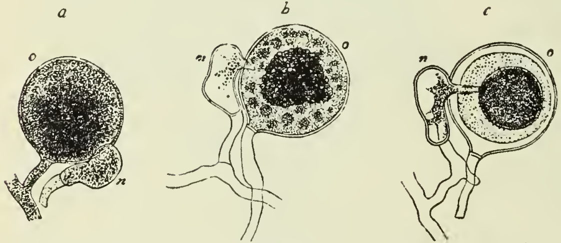
Spores of a Phycomycete. a—A mature sporangium. b—The same sporangium breaking open to free the motile Zoospores. c—Zoospores. (After de Bary.)

Nearly all the members of this group are water loving and grow best in very moist situations. For this reason a peculiar kind of spore which has the power of swimming about in water is commonly



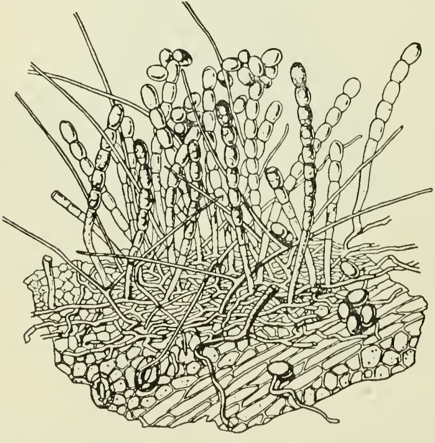
Typical sporangia of the Phycomycetes. a—A sporangium before opening to free the spores. b—Zoospores escaping from the sporangium. Highly magnified. (After de Bary.)

formed. These motile spores are called **swarm spores** or **zoospores.** They swim about for a short while, then come to rest, round up and germinate as an ordinary spore. Swarm spores are commonly formed in a sack-like enlargement of the mycelium or **sporangium.** Swarm spores have a very thin wall or covering and cannot survive any unfavorable conditions. Other kinds of spores are produced, however, which can resist very severe conditions and thus enable the fungi to live over winter and through periods of drought. These resistant or resting spores are usually formed by a sexual process (the fusion of two sexual cells, a male and female **gamete**) and are known as **oospores.** Oospores usually have a thick wall which, after living over the winter, breaks open to set free a number of zoospores similar to those formed in a sporangium.

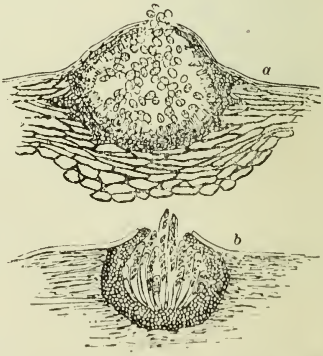


The formation of sexual spores in a Phycomycete. A—Young oogonium, o, and antheridium, n. B—Antheridium fertilizing oogonium. C—Fertilization completed. (After de Bary.)

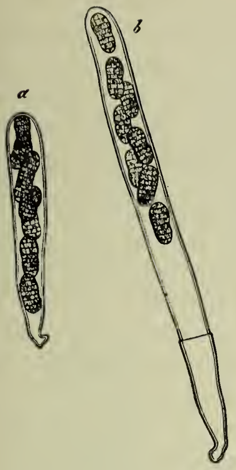
Such serious diseases as potato wart, late blight of potato and the many downy mildews are caused by fungi of this group.



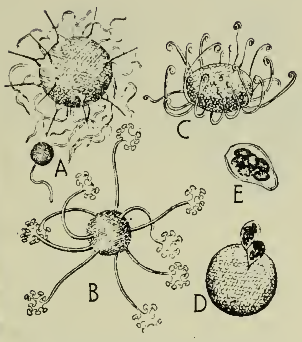
Asexual spores (conidiospores) of an Ascomycete. (After Tulasne.)



Two spore cases of an Ascomycete in a cross section. a—Asexual spore case (pycnidium). b—Sexual spore case (perithecium). (After Duggar.)



Typical spore bearing organs of an Ascomycete; two asci, each bearing eight ascospores. (After de Bary.)

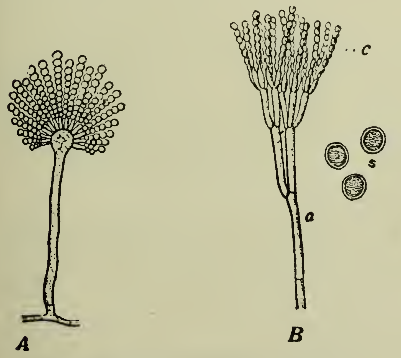


Several forms of spore cases (perithecia) of an Ascomycete. (After Curtis.)

The Ascomycetes are distinguished from all other fungi by the fact that every member of the group has some of its spores (those formed by a sexual process) formed inside of characteristic sacs known as **asci.** The asci always contain a definite number of spores (ascospores), usually eight. The asci are borne in special spore cases. These spore cases are cup-shaped in some forms and spherical or ball-shaped in others.

In addition to ascospores several other kinds of spores may be formed. These are usually without a sexual process and have a variety of forms. Some are borne free on the mycelium and are known as **conidiospores** or **conidia.** The mycelium on which conidia are borne are sometimes grouped together in the tissue of a plant, forming a compact mass and giving rise to a structure known as a pustule or **acervulus.**

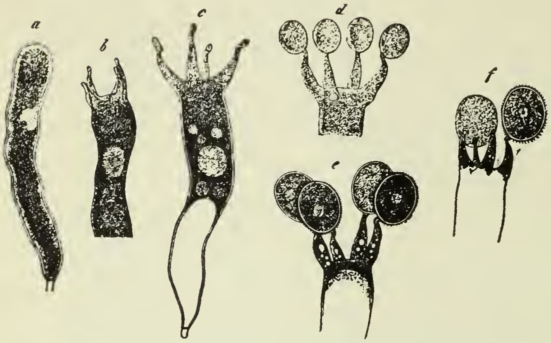
Other spores are borne in spherical or flask-shaped spore cases or **pycnidia.** Spores borne in a pycnidium are called **pycnospores.**



Asexual spores of two Ascomycetes. A—Aspergillus. B—Penicillium (A. after King; B. after Longyear.)

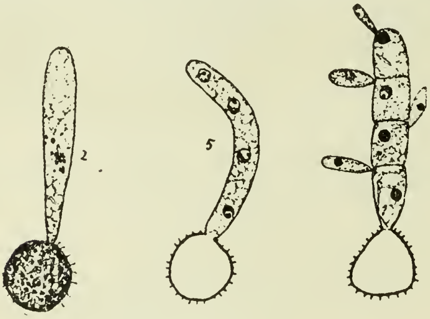
The Ascomycetes are not as dependent upon water as the Phycomycetes and never form zoospores. They make up the largest group of fungi and a great many of them are plant parasites. Peach leaf curl, plum pocket, brown rot of peaches, ergot of rye, leaf spot of alfalfa and the powdery mildews of many crops are some of the numerous diseases caused by fungi of this group.

The Basidiomycetes do not form their spores in sacs but bear them externally on more or less club-shaped stalks or **basidia.** Each basidium usually bears four spores. Spores born on basidia are spoken of as **basidiospores** or sometimes **sporidia.** The typical basidium is often modified into a short, usually four-celled tube, arising directly from a germinating spore. This modified basidium or **promycelium** is found in the rusts and smuts.

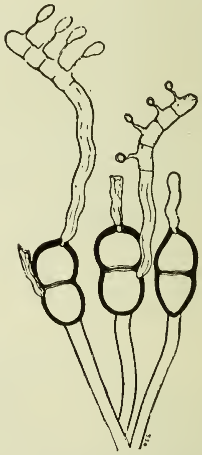


Spore formation in Basidiomycetes. The successive stages of development are in order of letters. (After de Bary.)

The Basidiomycetes also constitute a large group and include, in addition to the rusts and smuts, which are serious plant parasites, most of the common mushrooms.



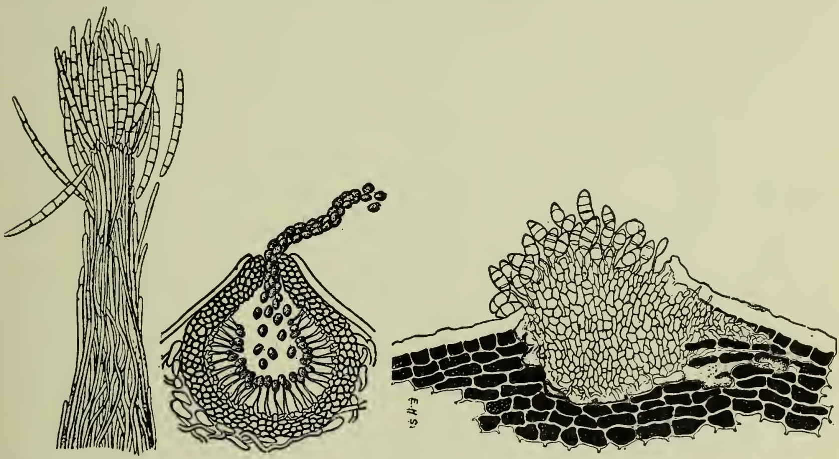
Germination of a smut spore showing a modified basidium. (After Harper.)



Germination of spores of asparagus rust showing a modified basidium. (After Smith.)

The Fungi Imperfecti, commonly spoken of as the imperfect fungi, constitute a group of miscellaneous individuals which do not form the type of spores that would identify them with either of the preceding groups. As their name indicates they are imperfect in that no sexual spores are formed. The spores which are formed closely resemble the asexual spores of the ascomycetes and it is very probable that if the sexual spores were known they could be transferred to the Ascomycete group. In fact, the sexual spores have been discovered for many species of this group and as a result they have been transferred to their proper place among the Ascomycetes. The spores of the imperfect fungi as mentioned above are formed much as the asexual spores of the Ascomycetes.

Flowering Plants—In addition to the bacteria, slime molds, and fungi there are a few higher plants wich draw their nourishment from other living plants and are therefore parasites. Mistletoe and dodder are the most common parasitic flowering plants. They obtain their food by sending root like structures **(haustoria)** into the tissues of the plant on which they are living and absorbing the already manufactured food.



Three methods of spore formation in the imperfect fungi.
a—Sporodochium c—Pycnidium. b—Acervulus
(a. after Tulasne; c. after Quaintance and Shear; b. after Smith.)

Insects and Other Animals—Many important and serious plant diseases are caused by insects, mites and other animals. This field, however, is best left to the Entomologist. Diseases produced by such organisms are not included in this bulletin.

NON-PARASITIC DISEASES

Among the agencies responsible for physiological or non-parasitic diseases may be mentioned **unfavorable chemical and physical conditions of the soil, unfavorable climatic conditions and mechanical injuries.**

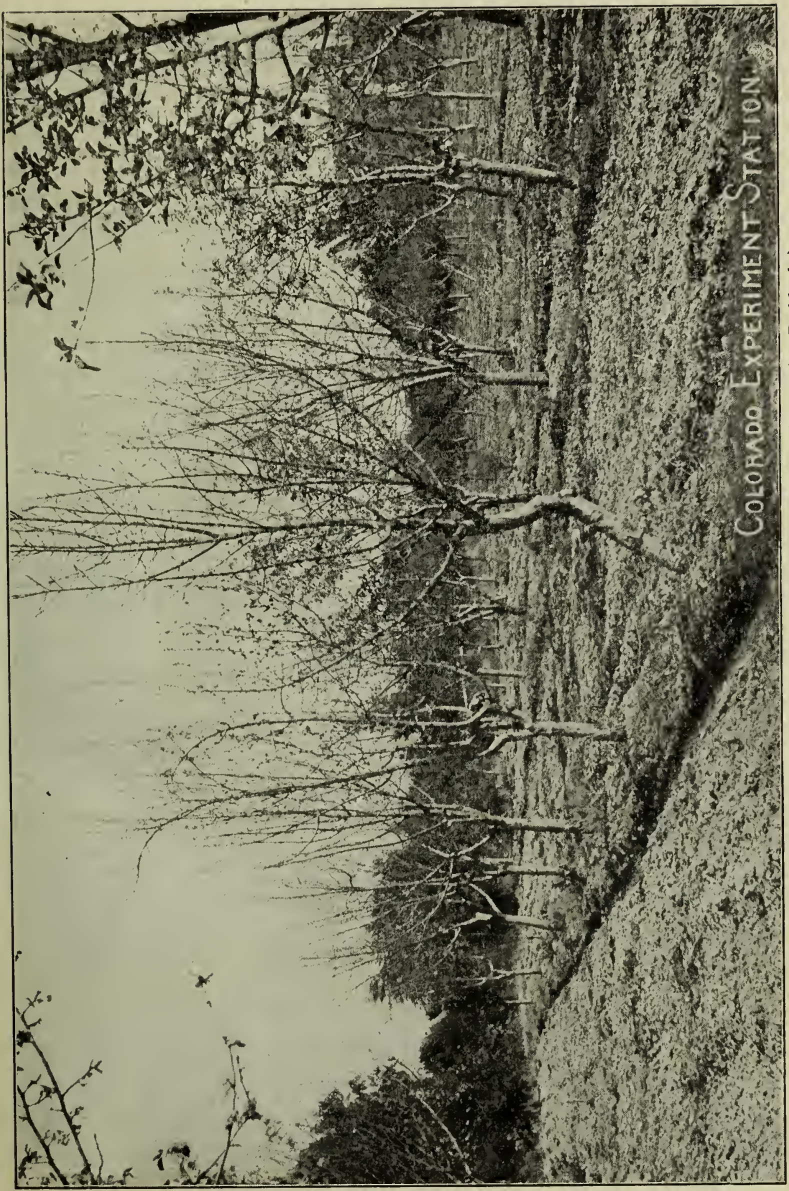
Unfavorable chemical conditions of the soil may be the result of either a deficiency or an excess of some element. The absence of potassium in the soil causes a dwarfing of plants and interferes with the manufacture of starch by the leaves. A deficiency of magnesium, iron, or nitrogen also reduces the amount of starch production in leaves. Too much nitrogen in the soil is said to make a plant more susceptible to frost injury.

Excessive quantities of nitrates in the soil are extremely injurious to plants. Certain Colorado soils have the power of fixing atmospheric nitrogen and this fixation often proceeds to the point where cultivated plants are completely killed over a localized area. Truck gardens, alfalfa, oat, barley and sugar beet fields often develop barren patches on which nothing will grow. Equally serious is the damage done to apple and cherry orchards in which many trees are completely killed. Often an entire orchard will be lost from this cause.

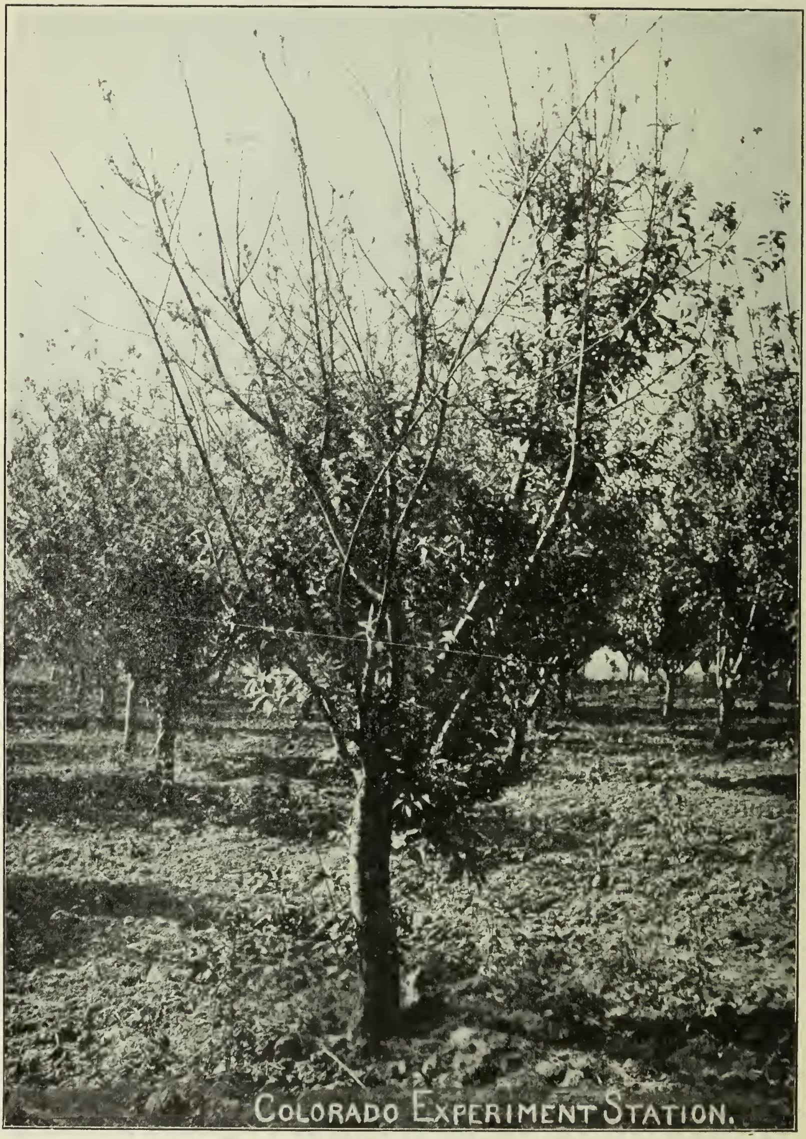
This excessive fixation of nitrogen is due to the activity of certain bacteria which live in the soil. These organisms take free nitrogen from the air and change it into the form of nitrates. The nitrates are dissolved in the soil water and as a result of evaporation become concentrated near the surface of the soil. This trouble is spoken of as "Nitre Injury."

The physical condition of the soil also has much influence on the health of plants. A heavy clay soil that packs easily is often injurious to plants. A course sandy soil often will not hold sufficient water for the plant growth. A lack of water will cause a plant to wilt or die. Too much water prevents air from reaching the roots of plants and brings about an unthrifty condition.

A nitre spot. (Original in Colorado Experiment Station Bulletin 155, by Headden.)


Colorado Experiment Station.

Apple trees killed by too much water. (Original in Bulletin 69, by Paddock.)

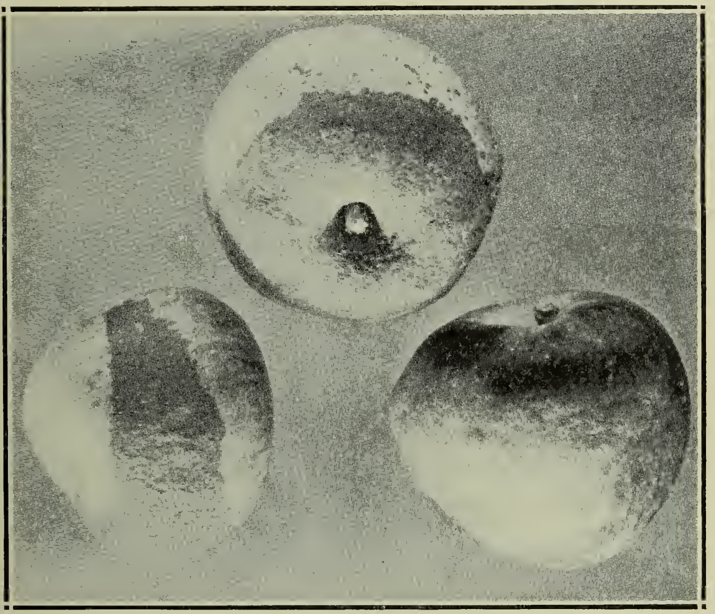

COLORADO EXPERIMENT STATION.

Injury due to unfavorable soil conditions. (Original in Bulletin 69, by Paddock.)

Unfavorable climatic conditions may often seriously injure plants. Very strong sunlight produces a condition known as sunscald. Too much shade interferes with the manufacture of starch by the leaves.

Frost injury and freezing are common among plants. In addition to the direct injury from frost or freezing such a condition often makes a plant more susceptible to certain parasitic diseases. For example, the bacterial stem blight of alfalfa develops extensively only after the alfalfa plants have been injured by frost. The bacteria gain entrance to the plant tissues through the cracks produced as a result of freezing.

The weight of ice and snow often breaks off the limbs of trees and thus opens the way for parasitic fungi. The fall of hail stones is a source of much damage to all forms of crops. Strong winds often are the cause of much damage. Limbs and buds are broken from trees; corn and small grain are sometimes blown down when the wind is accompanied by heavy rain. Heavy rains often injure the blossoms and prevent the pollination of fruit trees. Lightning injury is common although not of very great importance.



Frost injury on apples.

Smoke and gases from smelter and manufacturing plants have been shown to be injurious to plants of all kinds for many miles around. Trees and shrubs in the larger cities are often injured by smoke.

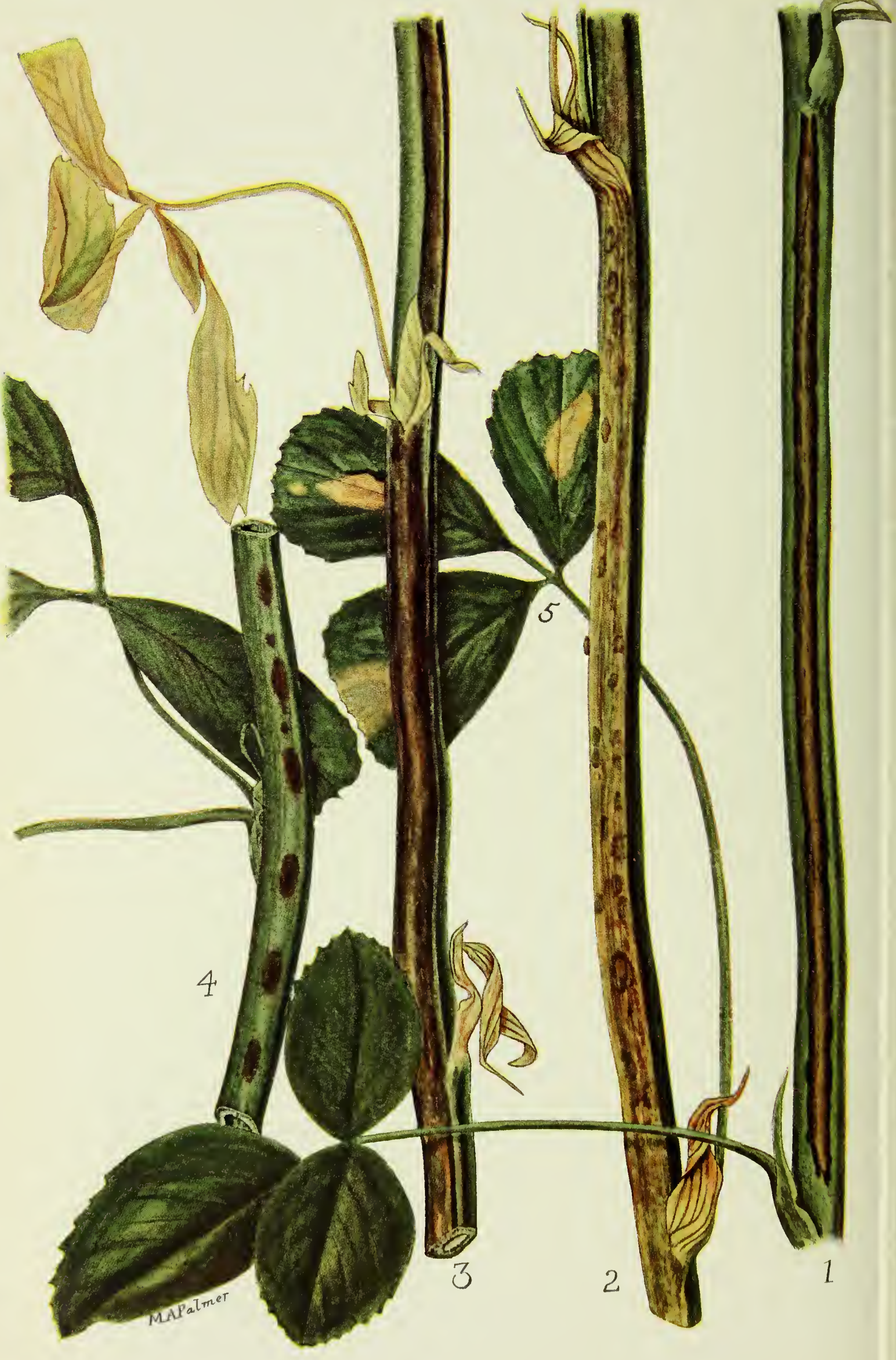
Mechanical injuries may be produced in a variety of ways. Fruit trees may be injured by cultivating too closely. Trees as well as herbaceous plants are frequently injured by hail. Young fruit trees are often barked by rodents or other animals. The opportunities offered for the entrance of parasitic fungi by mechanical injury are perhaps more important than any direct result of the injury.

Orchard fruits are often injured and disfigured by excessive and improper application of chemical sprays or by the application of sprays of too great concentration.

DISEASES OF UNCERTAIN CAUSE

Certain plants are subject to a disease commonly known as "mosaic" the cause of which is doubtful. The disease, as the name indicates, is characterized by a mottling or mosaic condition of the leaves of an affected plant. No parasitic organism large enough to be detected with a miscroscope can be found associated with the disease, yet the disease in some cases has been shown to be highly infectious. If the juice from a diseased leaf is injected into a healthy plant this plant will become diseased after a period of eight or ten days. This leaf juice or virus can be passed through the finest filter and yet retain its power of infection. For this reason the diseases are commonly said to be due to a filterable virus.

The Irish potato is subject to certain diseases known as curly dwarf, leaf roll and degeneracy, the causes of which are not thoroughly understood. The diseases are all characterized by a dwarfed condition of the plant and a low yield of tubers. Attempts to establish definite symptoms for each disease as well as experiments to determine their cause have been more or less confusing. The Plant Pathologists of the country, however, have gotten together and a concerted effort is being made to solve this important problem. Curly-top of sugar beets and peach yellows are other diseases, the causes of which are somewhat obscure.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PART II

DISEASES AFFECTING COLORADO CROP PLANTS

On account of the fact that no adequate survey of the plant diseases of the state has ever been made, the distribution, prevalence and severity of many of the diseases in Colorado are not known with any great degree of accuracy. Limited observations on the part of the writer and the fragmentary reports that have been received from time to time are the only sources of information available at present.

A survey of plant diseases in Colorado has been started, however, in co-operation with the office of Plant Disease Survey, of the United States Department of Agriculture, and it is hoped that within the next few years much valuable data will be collected on this subject.

In the following discussion no attempt has been made to treat all the diseases that occur on crop plants in Colorado. Only those known to be of considerable economic importance have been described. On the other hand a few diseases are included that have not yet been found in the state but which, on account of their serious nature and the liability of their introduction, it was thought best to mention at this time.

The crops are arranged alphabetically and the diseases of each are treated in somewhat the order of their relative importance. The figure in parentheses just following the name of the disease refers to a bulletin, which gives a more complete discussion of the trouble. The list of bulletins will be found at the back of this publication.

ALFALFA

Bacterial Blight (Pseudomonas medicaginis) (1)—This is one of the most serious diseases of alfalfa in Colorado, and is widely distributed over the southern half of the state.

Affected plants are stunted and lighter green in color than normal. Infection is chiefly on the stems. In early stages the stem has a watery semi-transparent, yellowish to olive green appearance along one side. A sticky amber liquid oozes from diseased tissue and soon dries to form a shiny cast which becomes black with age. Where the ooze collects in drops, light amber colored scales are formed. Affected leaves are water soaked and pale yellow in color.

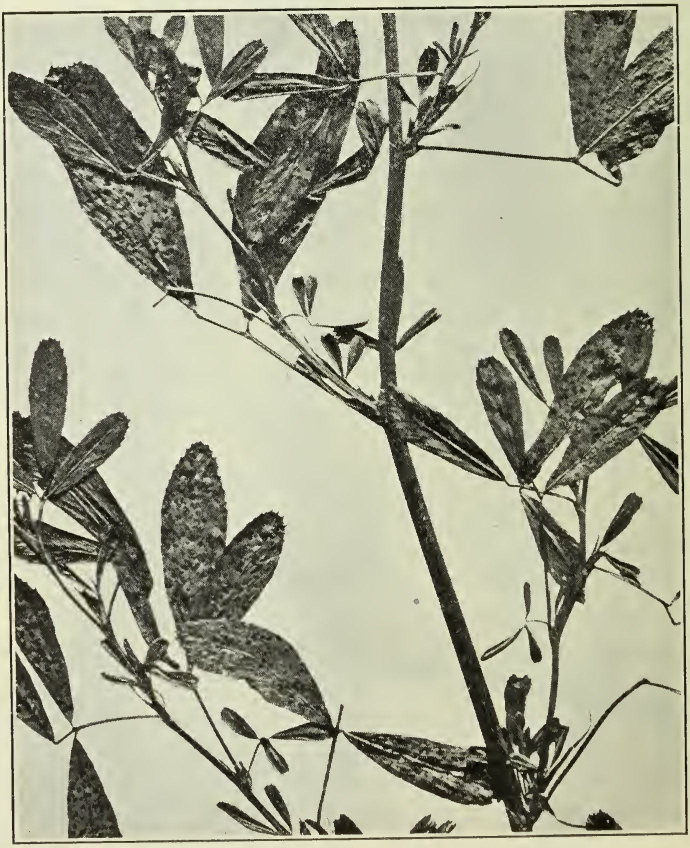
Colored Plate on opposite page shows the bacterial blight of alfalfa. Original was used in Bulletin 158, by Sackett.

They soon wilt, die and become dry and brittle. In one-year-old plants the disease may extend into the crown and roots and killing the entire plant.

The disease is caused by a bacterium which gains entrance into the plant through cracks caused by frost injury. For this reason the disease commonly affects only the first crop of alfalfa. It is most severe after late spring frosts.

Frosted alfalfa should be clipped as soon as danger of further injury from frost is past. This rids the plant of the cracked stems by means of which the bacteria enter and permit the production of new healthy shoots.

Leaf Spot (Pseudopezizza medicaginis) (2)—Leaf-spot is the most common and perhaps the most destructive of alfalfa diseases. It is widely distributed, occurring where ever alfalfa is grown.



Leaf-spot of alfalfa. (Original in Bulletin 212 by Robbins.)

Small brown or black spots are formed on the leaves. They are first evident on the upper surfaces. The spots are often very numerous, causing the leaves to drop off.

Leaf-spot is caused by a fungus. The black spots are the cup-shaped spore cases bearing a large number of spores. These spores live over the winter on dead leaves and are scattered about to the new leaves the following spring.

No practical control measures are known. The disease is considered as one of the necessary evils of alfalfa culture. Early cutting of heavily infected fields may reduce the loss of leaves.

Yellow-Leafblotch (Pyrenopezizza medicaginis)—This disease is similar in many respects to leaf spot. It is not as common, however, and has been known to occur in this country only since 1914. In certain localities where it is abundant it is said to produce a large loss of hay. Its distribution in Colorado is not known.

In appearance it differs from the leaf spot chiefly in that the spots are smaller and grouped together in large yellow blotches. The affected leaves become water soaked during rains and later shrivel and fall.

Yellow-leafblotch is produced by a fungus very similar to the one causing leaf spot and is almost as difficult to control. Careful mowing so as to leave no stray plants along fence rows and irrigation ditches will probably reduce the amount of the disease.

Downy Mildew (Peronospora trifoliorum)—Downy mildew is very injurious in certain localities under favorable conditions. It was first noticed in Colorado in 1906 when it was confined to a few localities. It has since spread over practically the entire state.

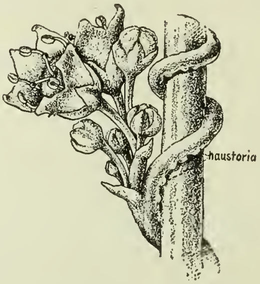
Only the leaves are affected. Light green or yellow green spots and blotches are produced. A gray downy growth appears on the under side of the affected leaves which changes to purple with age. The first crop seems to be more heavily infected than the succeeding ones.

The gray downy growth on the leaves is a mass of fungus growth bearing thousands of small egg shaped spores. These spores break open in drops of rain or dew, setting free a number of swarm spores, which swim about in the water for a while, then germinate and penetrate the leaves, producing a new disease spot.

Effective control measures are not known. Since the spores require lots of moisture for germination excessive irrigation should be avoided.

Dodder (Cuscuta spp.) (3)—Dodder is a common alfalfa parasite. It is widely distributed over the state although it is most prevalent in southern Colorado. Its injury is usually confined to relatively small tracts of alfalfa. These affected spots are covered with a tangled mat of yellow threads that twine closely around the plant. Affected plants are greatly stunted and are often killed.

The dodder plant is a true seed plant and has small white flowers. The dodder seed germinates in the soil and begins its growth just as any other plant but when it comes into contact with the alfalfa plant it twines itself about the stem, sends little rootlike structures **(haustoria)** into the alfalfa stems and robs the plant of its food. As soon as it has established itself on the alfalfa plant it loses its connection with the soil and lives entirely upon the alfalfa.



Dodder on alfalfa; an enlarged drawing to show method of attachment (after Longyear).

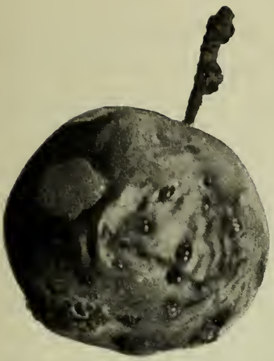
When affected areas are small, infected plants should be cut close to the ground beginning at the outside of the area and working inward; then burn the plants when dry and watch for any renewed growth.

If affected areas are extensive mow the entire crop closely, allow the hay to dry and then burn it. Plow the field and keep in cultivated crops for several years.

Dodder seed resemble alfalfa seed and are often found mixed with them. It is often spread and introduced into new areas in this way. Samples of all alfalfa seed should be sent to the Colorado seed laboratory for examination before planting.

APPLE

Fire Blight (Bacillus amylovorus) (4), (5), (6)—This is the same disease that affects pears. It does nearly as much damage on the

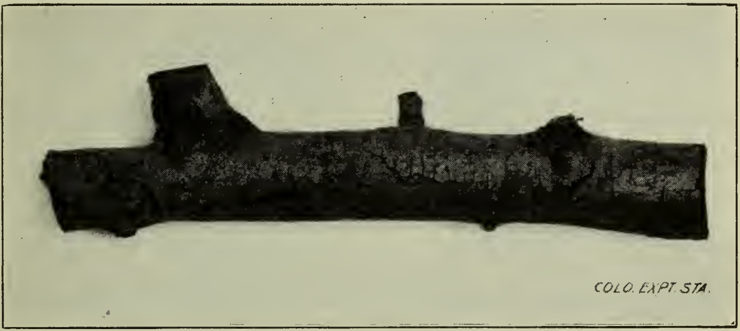


Fire blight. An infected apple showing the drops of ooze containing countless numbers of bacteria. (Original in Colorado Experiment Station Bulletin 84, by Paddock.)

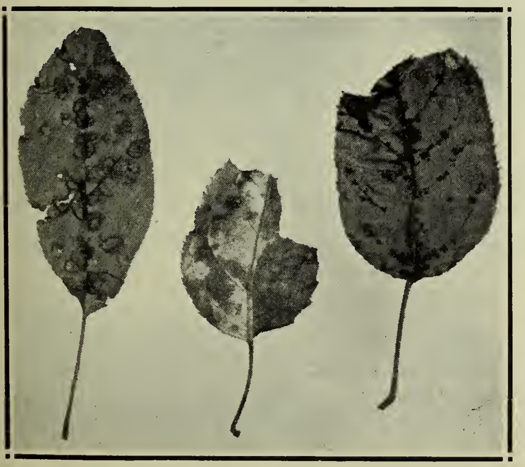
apple as on the pear. For a discussion of the disease see Pear.

Scab (Ventura inaequalis) (7)—Scab is one of the most serious diseases of the apple in the eastern states. It has been observed in Colorado in slight quantities for the past three years. It will in all probability become more prevalent as time goes by.

The disease affects leaves, flowers and fruit. On the leaves it makes its first appearance on the lower side as irregular olive-brown velvety spots. Later, spots more regular in outline appear which are on the upper surface of the leaves. On the fruit the spots are at first small, brown and smooth but later they become cracked and rough. Several small spots may grow together forming large scabby areas. When the attack is severe the fruit shrivels and falls.

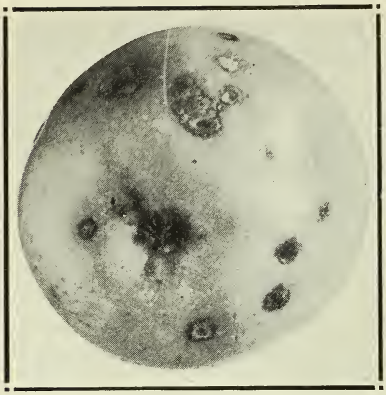


Fire blight. A hold over canker in which the bacteria live over the winter. Small drops of a sticky liquid containing large numbers of bacteria ooze from such cankers in the spring. (Original in Colorado Experiment Station Bulletin 177, by Sackett.)



Apple scab on leaves

The fungus causing scab lives over the winter on the dead leaves. Spores from these leaves infect young leaves and fruit in the spring. These form a new crop of spores and spread the disease from place to place.



Apple scab on fruit

Scab can be controlled by spraying with lime sulfur, one gallon of concentrated solution (testing 32 degrees Baume) to forty gallons of water. To this should be added two pounds of arsenate of lead to fifty gallons of diluted spray. Applications should be made as follows: (1) Just before the flower buds open. (2) Just after the petals fall. (3) Two weeks after the second spray. In dry seasons the latter spray may not be necessary.

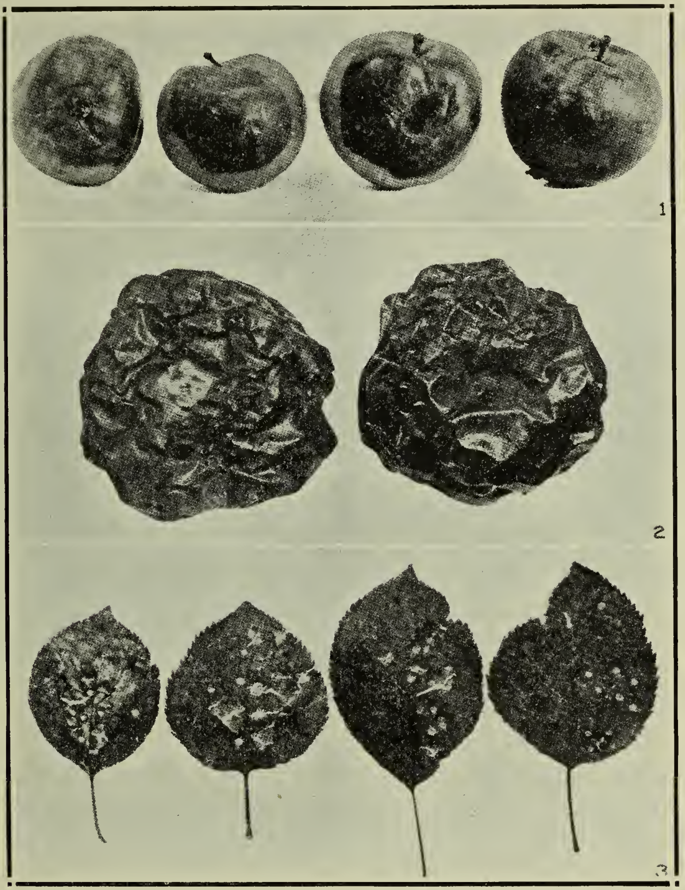
Experiments made in New York state have demonstrated that scab may be controlled by the application of a mixture of powdered sulfur and arsenate of lead. Applications must be made with a special dusting machine from both sides of the trees using one and one-half to two and one-half pounds of the mixtures per tree. Make at least three applications at the times recommended for the spray and in rainy seasons a third or fourth should be applied.

Black Rot (Physalospora cydonia) (8)—Black rot occurs more or less throughout the state. The disease affects the fruit, twigs and leaves. The fruit is attacked usually when nearly mature, decaying rapidly and becoming brown at first but later turning black. The apples remain firm for some time but eventually dry and shrivel up. Just beneath the skin little flask shaped fruiting bodies **(pycnidia)** are formed. Many thousands of spores are formed in these, which are pushed out through a small opening at the top and scattered about by the wind and rain to infect other fruits and twigs.

On the twigs the disease produces first a discoloration of the bark. The discolored area spreads gradually until the twig is girdled and it often spreads to the larger branches producing a rough canker. Large branches may also be attacked directly through cracks and wounds.

On the leaves brownish circular spots are formed which lead to premature shedding of the foliage.

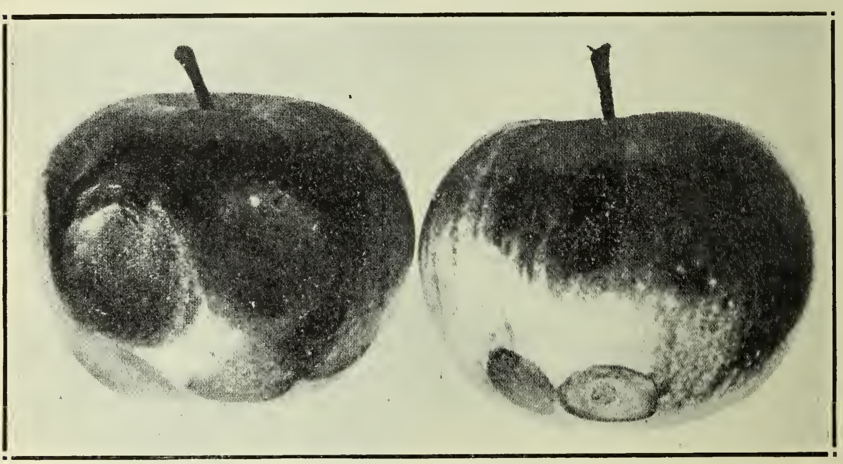
Black rot may be controlled by carefully cutting out all infected branches and spraying with (4-4-50) Bordeaux mixture. The first spray should be applied about the middle of July and should be followed by a second application about two weeks later. The lime sulfur spray recommended for control of scab may be substituted for Bordeaux mixture if applied sufficiently late in the season. Bordeaux mixture, however, is said to be more effective.



Black rot of apple. 1—Early stages of infection on fruit. 2—Later stage on fruit. 3—On leaves. (After Hesler.)

Bitter Rot (Glomerella cingulata) (9), (10)—The distribution and severity of this disease in the state are not known. It is, however, one of the most serious diseases of the apple in the eastern states and will very probably become of greater importance in Colorado.

Bitter rot attacks the fruit and twigs but is not known to occur on the leaves. It begins on the fruit as small light brown spots which rapidly enlarge finally involving the entire fruit. Small black spots soon appear on the surface of the larger spots. These are the fruiting bodies **(pycnidia)** of the fungus and soon break through the epidermis and free their spores in small pink masses. These spores are scattered about by wind and rain, causing secondary infection. Cankers are developed on the twigs, small limbs and fruit spurs. Large branches are seldom affected. The dead bark is cracked and roughened.

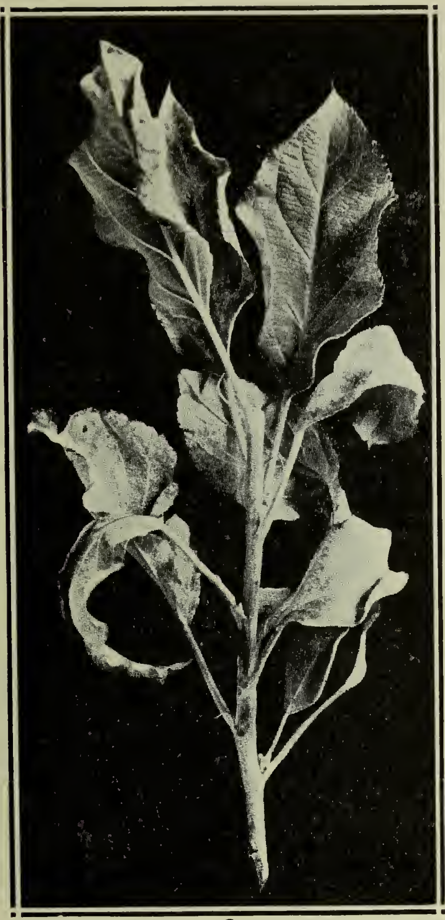


Bitter rot of apple. (After Garman.)

The lime sulfur spray is not effective for bitter rot. All infected twigs should be carefully cut out and Bordeaux (4-4-50) should be applied just before the buds open and again two or three weeks later.

Powdery Mildew (Podosphaera leucotricha) (12)—Nursery stock where ever apples are grown suffer more or less from powdery mildew. Both leaves and twigs are affected but the fruit is seldom injured.

A white or grayish powder is produced on the leaves; more often on



Powdery mildew on apple leaves

the under side. The twigs may be entirely covered with the same powdery growth. This powdery substance is made up of millions of small white spores **(conidia)** produced by the fungus which is growing over the surface of the leaf. These spores when blown from leaf to leaf germinate and produce new infections. In the late summer another form of spore is formed in small spherical spore cases **(perithecia)**. When the perithecia are formed they change the white grayish spots to dark smoky patches. The spores borne in perithecia on account of the protection afforded by the spore case are able to live over the winter. They are set free in the spring by the breaking open of the walls of the perithecia, and are scattered to healthy plants where they start the disease anew.

Powdery mildew is a difficult disease to control. All infected leaves and twigs should be cut out and destroyed. Ordinary lime-sulfur spray, to which has been added three pounds of iron-sulfate, has proven effective in some sections of the country. The spray should be applied first just after the petals have fallen and this should be followed by two additional applications at intervals of two or three weeks.

Crown Gall (Pseudomonas tumefaciens) (13)—Crown gall is most injurious in the nursery. The disease is characterized by large rough galls, occurring most commonly at the ground line. Galls are formed most frequently where root grafts are carelessly made. The galls may be either hard or soft. In some instances instead of galls large bunches of small fibrous roots are formed. This gives rise to the name "hairy root" which is sometimes applied to the disease.

Crown gall is caused by bacteria which live in the tissues of the plant stimulating it to abnormal growth. The same bacteria may cause galls on many other plants besides the apple.

Plant only disease free nursery stock and destroy all infected plants. Avoid injuring the roots in any way. In grafting care should be taken to use root and scion of approximately the same size. Most states have horticultural inspectors who inspect all nurseries at least once a year, and condemn all infected stock. This greatly aids in controlling the disease.

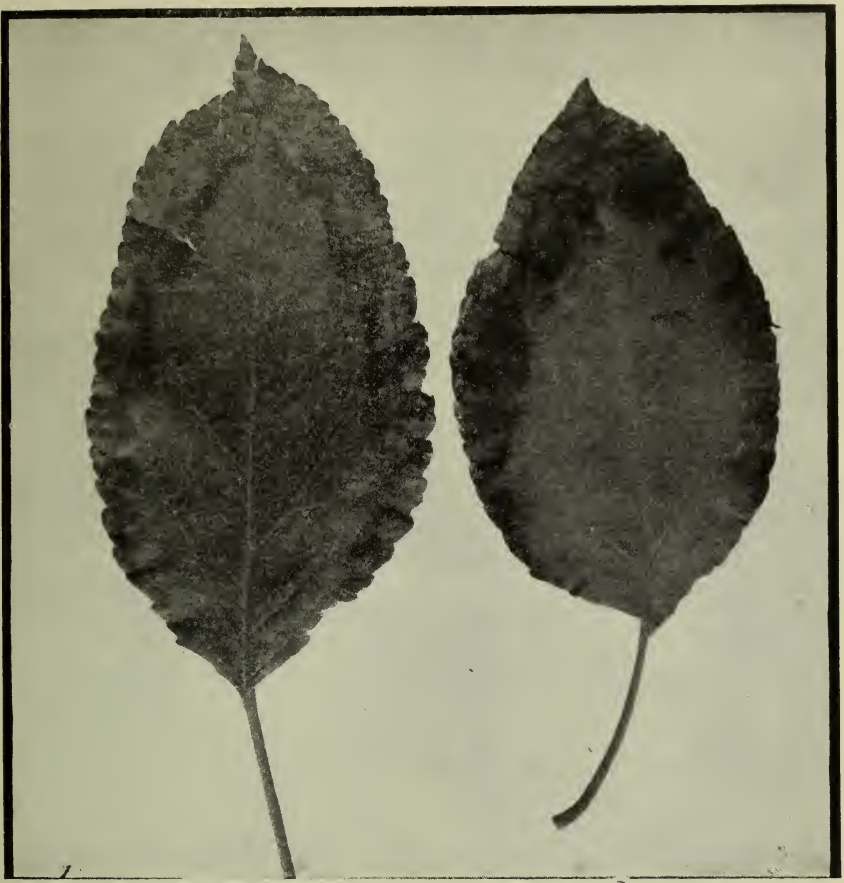
Nitre Injury (14), (15)—As stated in Part I of this bulletin, certain Colorado soils have the power of fixing atmospheric nitrogen in excessive quantities. The accumulation of large quantities of nitrates in the soil in this way is extremely injurious to many plants. The apple is extremely susceptible to nitre injury.

The leaves of affected trees have a characteristic appearance. A burning and drying begins at the tip and progresses rapidly along the margin and finally involves the entire trees and even whole orchards are completely killed. The process is a rapid one, whole trees being killed in a period of three weeks. Injury frequently follows irrigation. The water of irrigation brings the nitrates into solution, the condition in which they are the most injurious.

It has been shown that clean cultivation tends to hasten the accumulation of nitrates. Plowing under of cover crops is said to be an effective means of checking the formation of nitrates. This not only retards the accumulation of nitrates but vegetable matter, which is needed by the soil of most orchards, is added.

Good drainage is also an important factor in preventing nitre injury. Well drained soil will often take off sufficient nitrates in solution to prevent excessive accumulation.

Experiments have shown that soils containing large amounts of nitre and on which nothing will grow, can be reclaimed by flooding. Flooding is accomplished by preparing the ground in the usual manner for sowing grain. The area to be flooded is surrounded with an embankment of earth and water is led into the enclosure so that the entire piece of ground is covered to a depth of several inches. As the water seeps into the soil and drains off more water should be supplied keeping the surface covered for ten days. In this



Apple leaves showing nitre injury. Note the characteristic browning along margins. (Original in Colorado Experiment Station Bulletin 155, by Headden.)

way the accumulated nitrates are dissolved and washed out. Ground treated in this way should produce good crops.

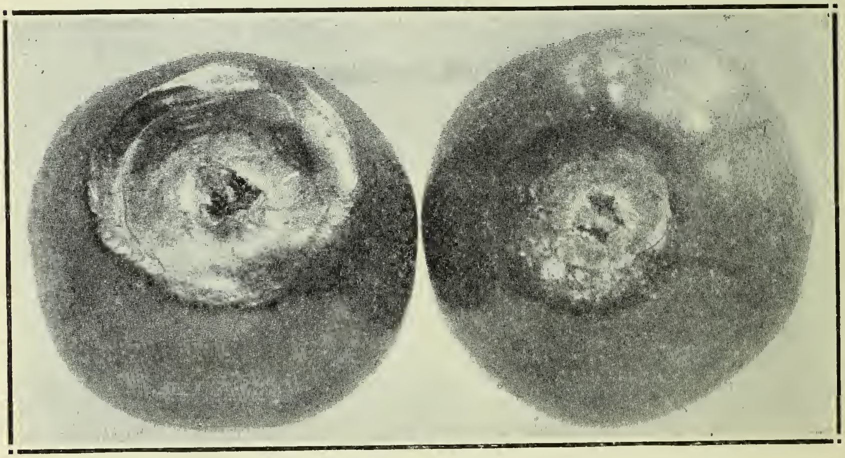
Apple Rot, Blue Mold (Penicillium expansum)—Blue mold is a destructive rot of ripe apples occurring most commonly in storage. Apples rotting from this cause give off a characteristic foul odor. The rotted area is soft and bright brown in color and spreads rapidly until the entire fruit is decayed. Under very moist conditions bluish tufts of spores are formed over the surface of the diseased fruit.

The decay is caused by a fungus which gains entrance through bruises or other mechanical wounds. In controlling the rot it is therefore important to prevent the skin of the apple from becoming injured in any way. One rotten apple in the barrel furnishes spores that are ready to enter any such wound on a healthy apple, so it is advisable to eliminate all apples showing the slightest sign of decay before putting the fruit in storage.

If the apples are fancy stock and it is desired to keep them a long time, it will probably pay to wrap each apple in a piece of clean paper.

Since apples decay more rapidly at high temperatures it is well to store them in cool dry places.

Black Mold (Alternaria sp.) (16)—A fruit rot which attacks the blossom end of ripe apples is common in Colorado and is often the source of much loss. The affected fruits show a dark brown sunken area at the base of the shriveled flower parts. The spots may be scarcely noticeable at time of harvest but they increase in size in storage until the entire apple is ruined. Cars of fruit which were apparently in perfect condition when shipped have shown as high as ten to twenty per cent of infected apples on reaching their destination. The Winesap seems to be particularly susceptible. A similar trouble has also been noted on Kieffer pears.



Apples affected with black mold. (Original in Bulletin 212, by Robbins.)

No extensive experiments have been made to determine methods of control, but it is very probable that if a fungicide spray was applied according to the plan recommended for other apple diseases, the loss would likely be reduced.

Frost Injury—(17), (18)—Injury from low temperatures is an important factor in apple growing. Frost injury may occur during the winter months or it may be due to late spring frosts. Injury occurring during the winter months is sometimes spoken of as winter injury.

All parts of the trees may be affected. Twigs, portions of large branches and roots are often killed by severe cold during the winter months. Late spring frosts usually injure leaves, fruit, buds, and blossoms. Affected leaves crimp and curl and ''frost blisters'' are often formed. Young fruits may be entirely killed or may be only slightly injured giving rise to the peculiar russeting or ''frost band.'' To prevent frost injury do not irrigate or cultivate late in the fall. Allow the trees to thoroughly mature before cold weather. Do not apply nitrogenous fertilizers except in early spring.

Spray Injury (19), (20)—Apple leaves and fruit are sometimes injured by improperly applying sprays or by applying sprays improperly prepared. Injured fruits show characteristic russet blotches. Leaf injury is in the form of irregular scattered light brown spots. If the spray is very strong holes may be burned into the leaves.

To avoid spray injury: (1) Follow carefully directions for the preparation of a spray mixture. Do not get it too strong. (2) Use pure chemicals. (3) Use a good nozzle and apply spray under high pressure in order to obtain a fine mist. (4) Be sure that the spray is thoroughly mixed.

NEGLECTED ORCHARDS

Throughout Colorado there are many orchards which are suffering from the lack of attention. No orchard can be expected to yield profit without a reasonable amount of care. Many orchards have never had a spray applied. Improper cultural practices, careless pruning and general neglect all go to produce the most favorable conditions for the growth and development of all fungus and insect diseases.

After large sums of money have been spent in establishing an orchard it is poor business not to give it proper care and make it yield its maximum production. Many orchards in Colorado that are not now paying interest on the investment could be made profitable by a little intelligent orchard management including judical use of sprays.

APRICOT

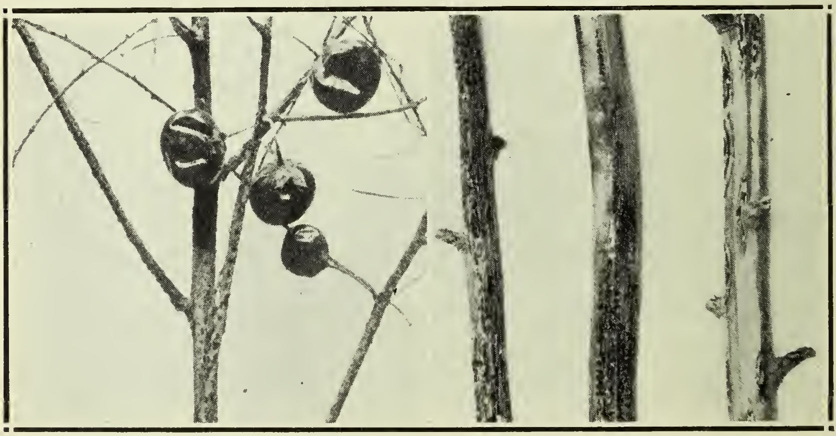
Black Knot (Plowrightia morbosa) (21)—see Plum. **Brown Rot (Sclerotinia cinerea)** (22), (23)—see Peach. **Fruit Spot (Coryneum beyerinckii)** (24), (25)—see Peach. **Scab (Cladosporium carpophi-**

lum) (26)—see Peach. **Crown-Gall (Pseudomonas tumefaciens)** (13) —see Apple. **Frost Injury** (17)—see Apple.

ASPARAGUS

Rust (Puccinia asparagi) (27), (28), (29), (30)—Asparagus rust was introduced into this country from Europe about twenty-five years ago. It spread rapidly over the entire country within a very few years and seriously threatened the asparagus crop where ever it appeared.

Rust affects the tall branching plants that spring up after the cutting season in spring and summer. Numerous oblong orange red spots are found on the stems and leaf-like branches. These spots are pustules containing thousands of yellowish brown spores which are blown about by the wind to healthy plants. Whenever one of these spores fall on an asparagus plant under the proper conditions of moisture and temperature it germinates and penetrates the plant forming a new pustule of spores. These may be produced in such abundance that the whole plant will take on a yellowish appearance and spores will be blown in clouds for some distance by the wind.



Asparagus rust. Summer stage.

Asparagus rust. Winter stage.

The rust saps the nourishment from the plant and hinders it in its food making process. As a result of this the underground stems do not receive the normal amount of stored material, consequently they fail to send up a good crop of "spears" the following year.

The red or summer spores are short lived and cannot live over the winter. In September and October a crop of hardy black spores are formed on the stems of the plant. The black spores live over the winter and germinate in the spring just in time to infect the young plants. In controlling asparagus rust, therefore, it is necessary to destroy by burning all diseased stalks. Asparagus often escapes from cultivation and grows along fence rows. Unless these stray plants are destroyed they will serve as sources of early spring infection.

Dusting with dry flowers of sulfur has been recommended for the control of this rust in California. The best grade of flowers of sulfur should be used. The first application should be made at the rate of 150 pounds per acre about three weeks after the last cutting of sprouts. This should be followed by a second application at the rate of 100 pounds per acre one month later. The sulfur should be applied in a fine dust preferably in the early morning while the plants are wet with dew.

Bordeaux mixture (5-5-50) to which has been added a resin mixture is also said to be effective. The resin mixture which should be added to the Bordeaux mixture is made as follows: resin, 5 gallons; potash lye, 1 pound; fish oil, 1 pint; and water, 5 gallons. Two gallons of this mixture diluted to ten gallons should be added to forty gallons of Bordeaux spray. A variety of asparagus known as Palmetto is said to be resistant to rust.

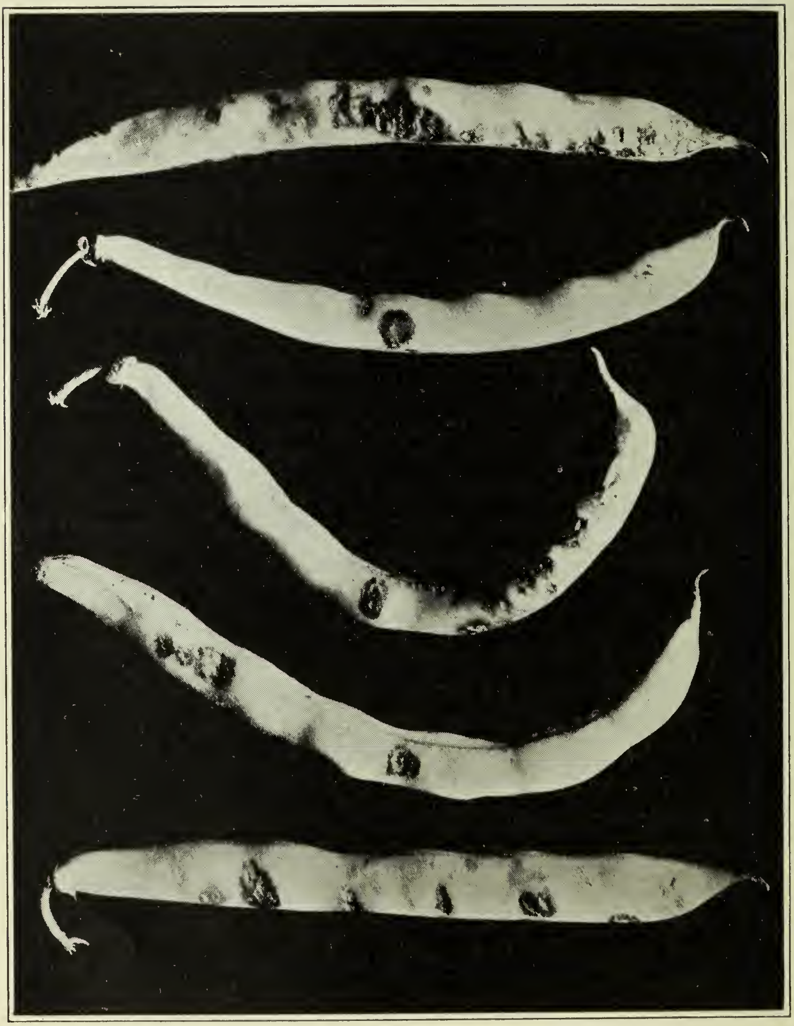
BEAN

Bacteriosis (Pseudomonas phaseoli) (31), (32), (33)—Bacteriosis or Bacterial Blight is one of the most serious diseases of the bean in Colorado. It attacks the stems, leaves, pods and seeds of both field and garden beans. Watery amber yellow spots ranging in size from tiny specks to areas of one-half inch in diameter are produced on the pods. The spots are irregular in outline and often have a red margin. If a spot occurs just over a seed within the pod the disease is likely to penetrate entirely through the pod and affect the seed.

The spots formed on the stems and leaves are very similar, at first, to those on the pod but rapidly turn brown, becoming dry and brittle. If the disease is severe the plants will shed their leaves and fail to mature seed.

Bacteriosis as the name implies is produced by bacteria which enter the plant through its breathing pores or wounds produced by mechanical injury. The organism lives over the winter on diseased seed.

Hand pick disease-free seed from healthy plants. Plant the seed



Bacteriosis of bean. (Original in Bulletin 226, by Kezer and Sackett.)

thus selected in a seed plot of ground that has never grown beans before. Use the seed from this plot to plant the larger fields. Seed for the seed plot must be selected in the field for diseased seed cannot be detected as they come from the thrasher.

Where ever practical all diseased vines should be destroyed by burning. Avoid cultivating beans when they are wet with dew or rain.

Anthracnose (Colletotrichum lindemuthianum) (31), (34), (35) —Anthracnose of bean only recently made its appearance in Colorado. In 1918 it was very prevalent and did much damage. In 1919, due perhaps to the very dry season, it was of little importance.

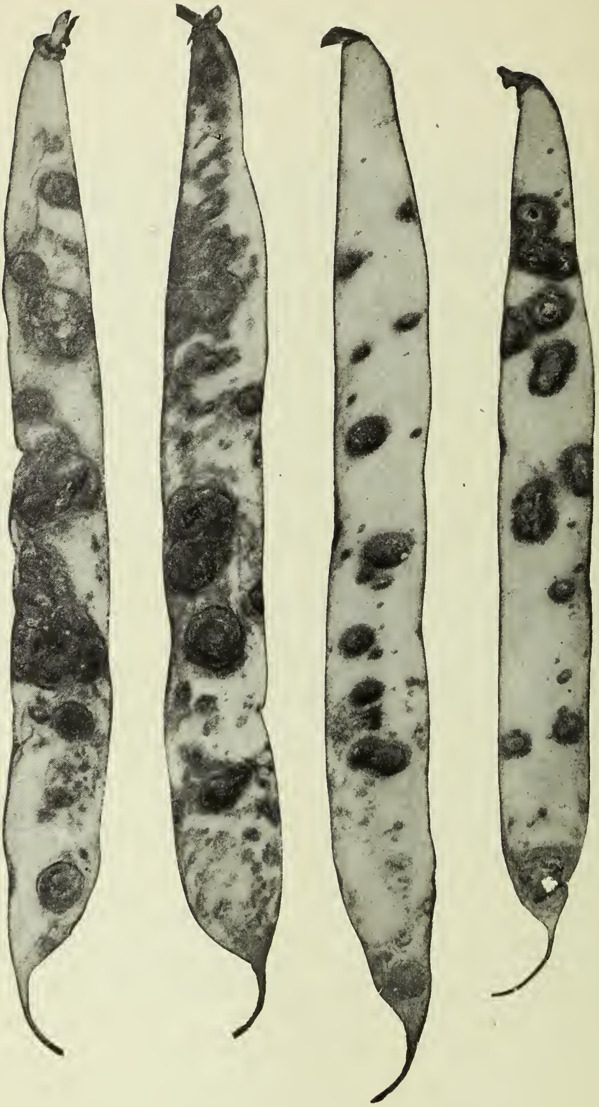
The disease is first noticed on the seed, leaves and stem of young plants. Dark reddish brown spots are produced on the stems and larger veins on the under side of the leaves. Reddish-brown circular, sunken spots are formed on the pods. The fungus works its way from these spots through the pod and into the seed. Seed infected in this way carry the fungus over from year to year.

The spores of the fungus produced in the center of the reddish brown spots are glued together by a sticky material, which is dissolved as soon as a drop of moisture touches it. Any disturbance of the plant while wet with dew or rain would tend therefore to spread the disease. For this reason beans should never be cultivated while they are wet from rain or dew.

Since the disease is carried over by diseased seed the same process of seed selection recommended for control of bacteriosis is applicable to the control of anthracnose.

Certain varieties of beans are said to be more resistant to anthracnose than others but recent work indicates that there are two or more specialized forms of the fungus causing anthracnose and that a variety may be resistant to one form but very susceptible to another. This is a question that should be further investigated. If different specialized forms of the fungus exist it is very important to know how many there are and where they occur.

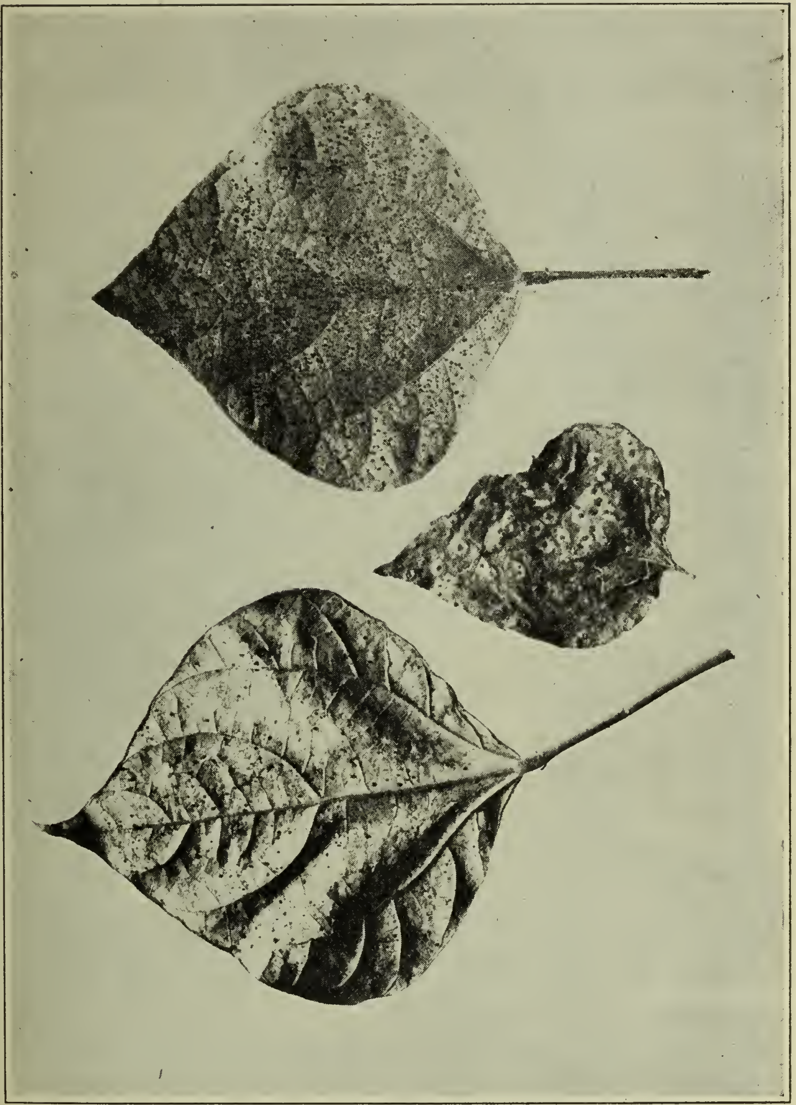
Stem Blight (Rhizoctonia sp.)—Beans throughout the state were seriously injured the past year by a fungus which attacked the stem just beneath the surface of the ground. Brick-red to dark brown irregular lesions were produced which often girdled the entire stem. These interfered with the transportation of food and greatly reduced the vigor of the plants. In many cases the injury was sufficient to kill the entire plant. The fungus causing the injury was not



Anthracnose of bean. (After Whetzel.)

definitely determined but is in all probability a species of the common soil fungus, Rhizoctonia.

A crop rotation, growing beans on the same soil not oftener than once in three years seems to be the only practical method of reducing the loss from this trouble. The disease is one that should be thoroughly investigated.



Rust of bean. (Original in Bulletin 226, by Kezer and Sackett.)

Rust (Uromyces appendiculatus) (36)—Bean rust is common in Colorado although it usually appears too late in the season to do much damage. In favorable years, however, it may appear sufficiently early to be rather destructive.

Small, raised, rusty-red, powdery spots are formed on the leaves commonly on the lower surface. These spots are pustules containing thousands of small reddish-brown spores which are scattered by wind and rain to healthy plants where they germinate and cause more spots. The disease interferes with the food making processes of the plants and decreases its vitality. Late in the season the reddish-brown spores are replaced by black ones which are sufficiently hardy to live over the winter. The disease is a difficult one to control. Since the black spores, formed on the leaves, carry the fungus over winter the destruction of affected vines should tend to lessen the amount of disease.

Certain varieties are said to be more resistant than others, but the question is one that needs further investigation.

Sunscald—A non-parasitic disease greatly resembling bacteriosis is common in Colorado. The brownish spots and streaks which resemble so closely the bacterial spots are the result of burning or scalding by strong sunlight. Sunscald is not of much economic importance as it produces no appreciable reduction in yield.

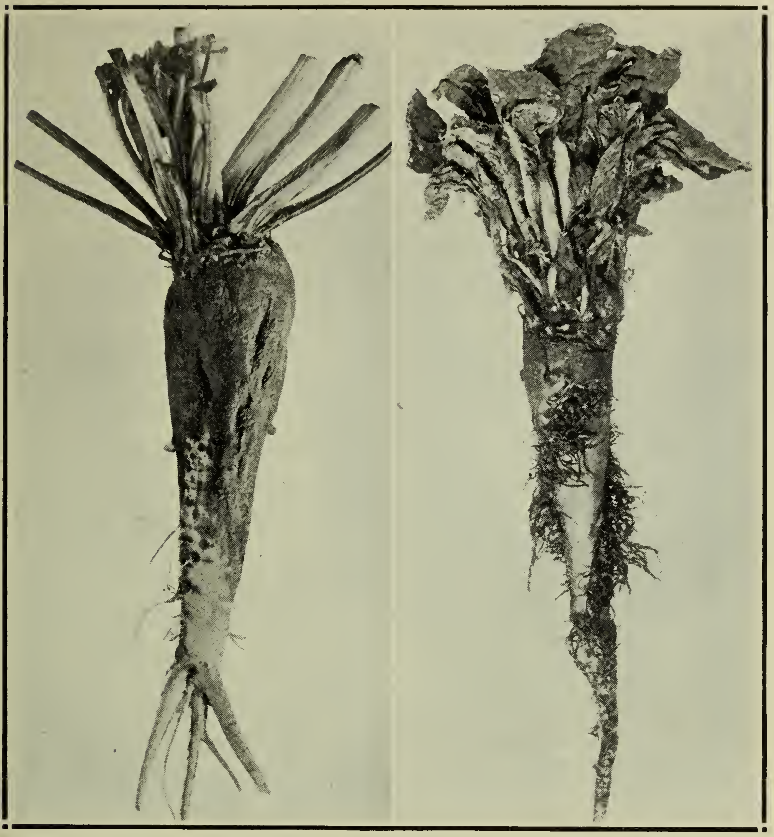
BEET

Root Rot (Rhizoctonia sp.)—Both garden and sugar beets are subject to root rot. The disease first becomes evident by a drooping and wilting of the leaves. On examination the outer leaves are seen to be rotted at the base. This decay soon spreads into the crown and root causing the infected area to turn brown. Cracks often appear and in severe cases the entire beet may be destroyed.

Moist weather and excessive irrigation favor the development of the disease. The fungus causing the disease lives from year to year in the soil. Careful irrigation and crop rotation are the most practical means of reducing the loss from root rot.

Curly Top (38), (39)—Curly top is one of the most destructive diseases of the sugar beet, especially in the western beet fields. It is characterized by an inward curling of the leaves, checked growth and the production of an abundance of hairy roots.

Curly top is produced by the bite of the sugar beet leaf hopper (Eutettix tenella). The bite of the insect is not sufficient to produce the disease, but the insect carries within its system some substance

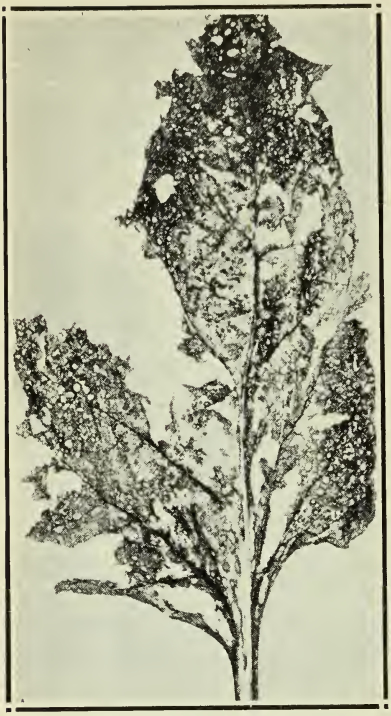


Rhizoctonia root-rot of sugar beet.

Curly dwarf of sugar beet.
(After Townsend.)

which when injected into the plant brings about the diseased condition. The insect gets this substance into its system by biting a diseased beet. A leaf hopper which has never been upon a diseased plant may bite a healthy beet without producing the disease, but if it is on a diseased beet before it bites a healthy one the disease will follow.

It has recently been shown that a number of other plants including a few common weeds may also be affected with curly top. A leaf hopper from such a plant may carry the disease to healthy beets. It is probably in this way that the disease lives over the winter. Curly Top is a difficult disease to control. The destruction of the leaf hopper would probably reduce the amount of curly top but this is not very practical.



Cercospora leaf spot of beet.
(After Townsend.)

Leaf-Spot (Cercospora beticola) (40)—This leaf-spot affects both garden beets and sugar beets although it is much more injurious on the latter. It is common where ever beets are grown and is often the cause of much loss in the yield of sugar beets in Colorado.

The spots first appear on the outer leaves as small brown dots often with a purple margin. As the spots increase in size usually reaching one-eighth to one-fourth inch in diameter, the centers become ashen gray due to the formation of thousands of spores of the fungus. As soon as the spores are formed they may be scattered about by wind and rain and irrigation water to healthy leaves causing new spots to form where ever they fall. The spots may become very numerous affecting the leaf stalk as well as the blade. Badly affected leaves become brown and dry. The destruction of outer leaves and the formation of new ones in the center often causes the crown to become considerably elongated.

Spraying with Bordeaux (4-5-50) is said to be effective though somewhat impracticable. It has recently been shown that the first infection in spring may come from infected seed and that plants raised from seed treated with a formaldehyde solution (15 parts to 1,000 for seven minutes) attain a better development and are more productive than those grown from untreated seed.

The most common source of infection however is the old beet top material left on the ground after the preceding harvest. Removal of infected beet tops or deep plowing to cover up all such refuse will greatly reduce the amount of the disease.

Beets should not be planted on the same soil oftener than once in three years and such rotated fields should be separated from unrotated fields by at least one hundred yards.

Leaf-Spot (Phoma betae)—A leaf spot differing from the one described above is common on sugar beets throughout the state although it never grows as serious. The spots characterizing the injury produced by **Phoma betae** are light brown in color and from a quarter to one-half inch in diameter. Numerous small black specks, often arranged in concentric rings are found scattered over the surface of the spots. These black specks are the small flask shaped spore cases **(pycnidia)** of the fungus. The spores escape from these pycnidia and are scattered to healthy leaves where new spots are formed. The same control measures recommended for the control of Cercospora leaf spot apply to Phoma leaf spot.

A crown rot of mature beets and a damping off of young beets are caused by this same fungus.

Nematodes* (Heterodera schachtii and Heterodera radicicola) (37)—Nematodes, or eel worms as they are sometimes called, are very small eel-like worms that live in the soil and feed upon the roots of various plants. There are two nematodes attacking sugar beets in Colorado, the sugar-beet nematode and the root-knot nematode. Both species, so far as known, occur on river bottom lands more commonly than on uplands. The damage caused by them is greatest on light, sandy soil. This is due to the fact that the nematodes thrive better in such soil.

The effect upon sugar beets is two-fold. The yield is very greatly lowered and the sugar content of the crop reduced. In severe cases the young beets are killed and the stand destroyed.

Control measures consist of (1) preventing the spread of the nematodes, (2) preventing their multiplication.

1. Nematodes are spread: By waste water from infested fields; on implements used in working infested land; by being carried from infested fields to uninfested ones on the feet of animals and persons working them; by feeding beet tops from infested fields and applying the manure produced to uninfested land.

2. The multiplication of nematodes is checked by rotation of crops. Small grain, with the exception of oats, may be used where land is infested with sugar beet nematodes. Corn, cabbage, turnips, oats, and beans should not be planted on infested land.

Where the root-knot nematodes occur any of the small grains or corn may be planted. Potatoes, cabbage, tomatoes, and other vegetables or root crops should not be grown.

BLACKBERRY

Anthracnose (Plectodiscella veneta) (41), (42), (43)—see Raspberry. **Leaf-Spot (Septoric rubi)**—see Raspberry.

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*Thanks are due to Mr. Asa C. Maxson of the Great Western Sugar Company for the information on this disease in Colorado.

CABBAGE

Black-Rot (Pseudomonas campestris) (44)—Black-rot at present is not a serious disease in Colorado. In some sections of the United States it is one of the most destructive of cabbage diseases. Black-rot makes its first appearance along the edges of the outer leaves. Affected areas wilt, turn yellow and dry up. The veins of the leaf become blackened. The disease spreads along the veins until it reaches the main stem from where it rapidly spreads to all parts of the plant producing the characteristic black rot. Frequently a plant may be affected one one side only in which case the affected side appears dwarfed. Much loss is often suffered in storage when slightly infected plants are stored. Infection may occur in seedling stage, killing the entire plant in a very short time.

Black rot is a bacterial disease. The bacteria may gain entrance to the plant through breathing pores or mechanical injuries, but they enter more commonly through the water pores along the margin of the leaves. The organism lives over the winter in the soil and decayed cabbage refuse and also on seed from diseased plants.

Since infection may take place in the seed bed the plants should be closely watched to see that no infected plants are taken to the field. Crop rotation is necessary for effective control. Seed should be disinfected by soaking in corrosive sublimate solution (1-1000) for fifteen minutes or in formaldehyde (1-200) for twenty minutes.

Black-Leg (Phoma lignam) (44)—Black-leg is one of the most destructive of cabbage diseases. Often the greater portion of the crop may be destroyed.

The disease is first noticed as irregular sunken spots with a purplish border on the stems near the surface of the ground. The spots increase in size until the stem is completely girdled. The plant is, of course, weakened and ultimately dies. Small black dots then appear all over the surface of the diseased tissue. These are the spore cases or pycnidia containing the thousands of spores which are set free to affect new plants.

Crop rotation and destruction of all infected plants are the most reliable control measures. Seed from diseased fields should never be planted unless thoroughly disinfected with corrosive sublimate. Seed should be planted in beds containing soil that has never grown cabbage before.

Yellows (Fusarium conglutinans) (45)—The prevalence of this disease in Colorado is not known. It is one of the most important in the states further east.

Affected plants, as the name indicates, are characterized by the yellow color of their outer leaves. The plants are stunted and the lower leaves show a tendency to drop at the slightest touch. Young seedlings are often affected in which case the plant rapidly wilts, turns black and dies.

Cabbage yellows is due to a fungus that lives from year to year in the soil, gaining entrance to the roots and checking the flow of water from the roots to the rest of the plant. Crop rotation and the use of resistant varieties are the most practical means of controlling the disease. The Wisconsin Agricultural Experiment Station has had remarkable success in selecting strains of cabbage resistant to yellows.

Club-Root (Plasmodiophora brassicae) (46)—Club-root is not common in Colorado. In the eastern states, however, it is a very destructive disease. The roots of infected plants become much enlarged and swollen, each infected root taking on a peculiar spindle shape. A dwarfing of the remainder of the plant results. In warm, dry weather infected plants wilt sooner than healthy ones. In severe cases the plant may die. Club-root is due to infection by a slime mold which gains entrance into the roots from the soil. The little slimy masses of protoplasm, that make up the body of the organism, work their way from cell to cell in the root, stimulating it to abnormal growth. Late in the season these masses of protoplasm inside the root break up into small round spores. When the root decays these spores are set free in the soil. Under proper conditions these spores germinate to form new masses of protoplasm which may affect new cabbage plants.

Since the organism causing club-root lives in the soil, crop rotation is one of the best control methods. All roots of infected plants should be destroyed. A heavy application of lime (100 bushels per acre) every few years is said to be an effective means of control.

CELERY

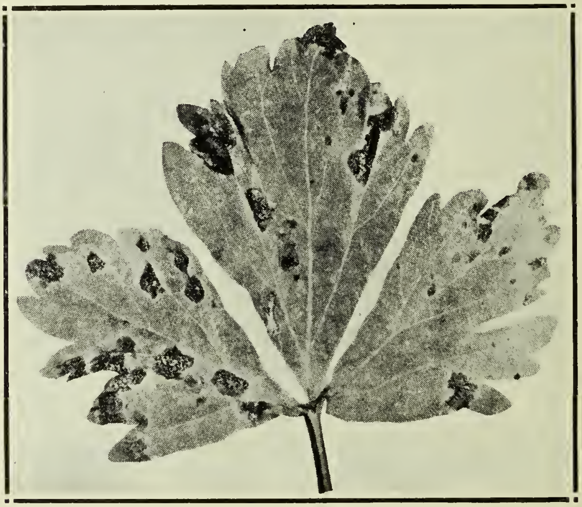
Late Blight (Septoria petroselini var. apii) (47)—This is by far the most serious disease of celery in Colorado. Few fields are free from the trouble and many are seriously damaged.

Both leaves and stems are affected. Small light brown spots are first formed on the lower outer leaves. The spots later turn black and if the leaf is badly affected it will dry up and die. Many small black spore cases **(pycnidia)** are found over the surface of the spots and imbedded in the leaf. Many small but long needle-shaped spores are set free from a round opening in the tops of the pycnidia.

The spores are scattered to healthy plants by wind and rain and irrigation water where they germinate to produce new spots.

On the stems the spots are similar to those on the leaves often occurring in clusters, uniting to form larger spots which may cover the greater portion of the stem. Such infected stalks soon turn brown and soft, finally dying and drying up.

Late blight can be controlled by spraying with Bordeaux mixture (5-6-50). The first spray should be applied to the seed bed at the rate of thirty gallons per acre. If the disease is prevalent it would be advisable to spray the seed bed at least twice. After the plants are transplanted to the field, spraying should begin at the first appearance of blight. Spray once a month thereafter until the danger is past. In the field 50 to 100 gallons to the acre should be applied according to the size of the plants. Effective control depends upon the thoroughness with which the spraying is done.



Late blight of celery. (After Coons and Levin.)

Early Blight (Cercospora apii)—This is also a leaf-spot disease but is not as serious as the late blight. Large irregular dead spots are formed on the leaves earlier in the season. On account of the slight losses from early blight spraying is not considered profitable.

Root-Rot (Rhizoctonia sp.)—Celery is often destroyed by a root rotting fungus which attacks the root at an early stage of development, causing them to decay with a moist soft rot.

Crop rotation and the avoidance of over irrigation tend to reduce the amount of the trouble.

CEREALS

The diseases affecting the various cereals are more or less similar and therefore are discussed as a group.

Smuts (40), (48), (50), (51)—The smuts of cereals are perhaps the most destructive of all plant diseases. They were responsible for a loss of nearly 135,000,000 bushels of grain in the United States in 1917. The loss in Colorado alone was almost 2,000,000 bushels.

The smut affecting one kind of plant is so specialized that it cannot grow on any other species of plant. Each cereal has its own smut or smuts which can affect that cereal and no other.

CORN

Corn Smut (Ustilage zeae)—There is only one smut of importance affecting corn. It is very common in Colorado and is the source of much loss.

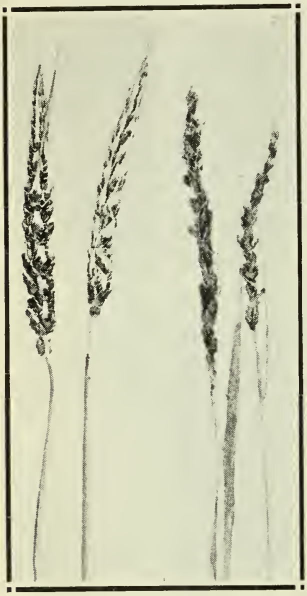
Corn smut.

Large black smut masses are formed on any part of the corn plant above ground including ears, stems, leaves, and tassels. Millions of spores are contained in these smut masses and are scattered broadcast by the wind. Each of these spores which may live over the winter in the soil, germinates in the spring and forms dozens of still smaller spores that are easily blown about by the wind. These secondary spores may infect any part of the corn plant and cause a new mass of spores.

For obvious reasons seed treatment is not effective in controlling corn smut. It has been shown that smut spores may pass through the digestive tracts of animals uninjured. Furthermore such spores germinate in manure piles which form ideal places for the production of the secondary spores in great quantities. It is plain therefore that smutted corn should be fed to animals and only rotted manure should be placed on corn fields. Since the spores may live in the soil, crop rotation is advisable.

BARLEY

Covered Smut (Ustilago hordei)—This is the most common and destructive of the two smuts affecting barley. Fields often contain as high as 35 or 40 per cent smutted plants. The barley grains are replaced by a mass of black dust-like spores which are the "seed" of the smut fungus. These are scattered about in threshing, some of them alighting on the surface of healthy grains of barley where they remain until the grain is planted. The smut spores germinate at the same time that the grain of barley germinates, and penetrates the tender seedling and grows up through the stem. At fruiting time the smut fungus grows out into the flowers and the developing kernel is replaced with a mass of black smut spores.


Covered smut of barley Loose smut of barley

Since the smut spores live over on the surface of the grain, the logical way to control the disease is to treat the seed with a disinfecting solution that will kill the spores without injuring the grain. A solution of formaldehyde in water has been found effective for this purpose. See directions for seed treatment in Part III.

Loose Smut (Ustilago nuda)—Loose smut is common in Colorado but is not as destructive as covered smut, seldom causing more than 5% loss. Loose smut differs from covered smut in that the spore masses are not enclosed by a membrane but are borne loosely on the stem. Because of this fact the spores are scattered about by the wind as soon as they are formed which is just at the time that normal uninfected plants are blooming. Some of these smut spores fall upon the flowers of the blooming barley and grow directly into the developing grain. The grain hardens and becomes mature, however, before the fungus can form spores. The fungus is thus enclosed in a grain of barley that to all appearances is perfectly normal. When this grain germinates, the fungus also begins to grow and grows up through the stem replacing the developing kernels with a mass of loosely borne spores. Thus we see that the loose smut differs from the covered smut also in the time and manner of infection.

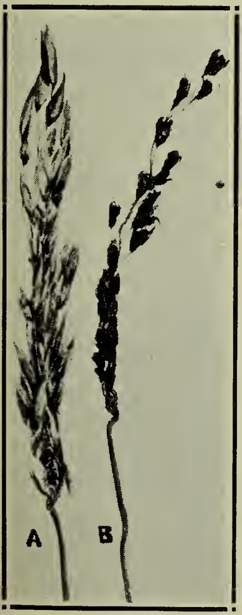
Because of the fact that the loose smut fungus lives over on the inside of the grain rather than on the surface the ordinary formaldehyde treatment is not effective. A complicated hot water treatment is the only known method of killing the fungus within the kernel without injuring the grain.

Because of the difficulty in applying the hot water treatment without injuring the seed it is advised that this method be used only for treating a small quantity of grain. The small lot of treated grain should be planted in a seed plot separated as far as possible from other grain fields. The seed from this seed plot should be used in planting the larger fields the succeeding year. The resulting crop should be free of loose smut.

For directions in applying the hot water treatment see Part III.

OATS

Oat Smuts (Ustilago avenae and **levis)**—There are two smuts of oats, a loose smut and a covered smut, but they differ so slightly that for all practical purposes they may be considered as one. Both are extremely destructive. The life history of the oat smuts is practically the same as that of the covered smut of barley and therefore the formaldehyde treatment is effective.



Smut of oats. A—Covered smut. B—Loose smut.

Flag smut of rye. (After Stakman and Levine.)

RYE

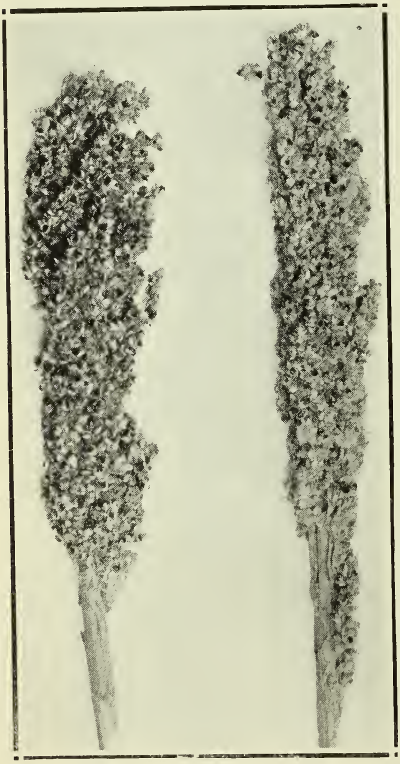
Flag Smut (Urocystis occulta) (52)—This is the only smut affecting rye. Masses are formed on the leaves and stems as well as the kernels. Affected plants are usually stunted and seldom produce normal heads. On the leaves long gray blisters are first formed which on breaking open expose a mass of black spores. Similar blisters are found on the stems often causing them to become twisted and curved. If heads are produced they are nearly always empty or else the kernels have been replaced by masses of smut spores.

The spores may live over either on the surface of healthy rye kernels or in the soil. The formaldehyde seed treatment together with crop rotation is effective in controlling rye smut.

SORGHUM

Under the name sorghum are included milo, kaffir, feterita, durra, broom corn, sudan grass and shallu.

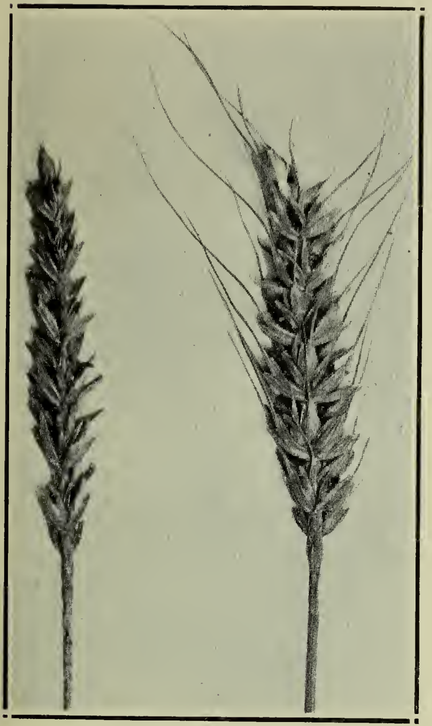
Kernel Smut (Sphacelotheca sorghi)—This is the most common smut of sorghum. As the name indicates the kernels alone are affected, each kernel becoming a mass of smut spores. The head retains its usual shape and form. The spores live over on the surface of normal seed and infect the plant as soon as the seed germinates. The formaldehyde treatment is effective. Milo is resistant to all smuts.



Kernel smut of sorghum.

Head Smut (Sorosporium reilianum)—Head smut is not common in Colorado. The entire heads of infected plants become a large deformed mass of smut spores. Head smut differs from kernel smut in that the spores are not necessarily carried with the seed but is wind distributed affecting the plant either from the soil or above ground. Seed treatment therefore is not effective. Milo is resistant to head smut as well as to kernel smut.

WHEAT

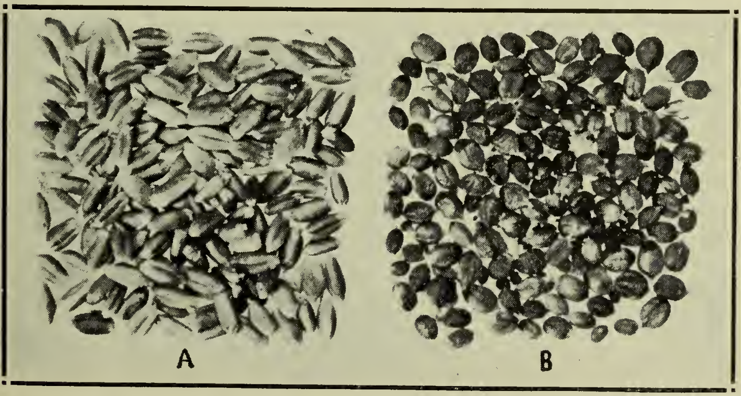


Bunt or covered smut of wheat.

Covered Smut or Bunt (Tilletia laevis and tritici)—Covered smut is the most destructive of the smuts affecting wheat. It is estimated that this smut was responsible for a loss of 21,971,000 bushels of wheat in the United States in 1917.

The kernels alone are affected, each kernel being transformed into hard smut balls retaining somewhat the shape of the normal grain. Smutted grains, however, are usually darker in color, lighter in weight and more round in shape. A smutted kernel when crushed breaks up into a mass of black spores and gives off a characteristic foul odor resembling the smell of decayed fish.

The spores are carried over on the surface of the kernels and infect the germinating seedling. The formaldehyde seed treatment is therefore effective.



A—Healthy wheat kernels. B—Bunted wheat kernels.

Loose smut of wheat.

Loose Smut (Ustilago tritici)—Loose smut of wheat is identical in all respects to loose smut of barley described above with the exception that it can affect only wheat, while the loose smut of barley can affect only barley. The hot water treatment only will control loose smut.

Flag Smut (Urocystis tritici) (53)—A flag smut of wheat very similar to flag smut of rye has recently been discovered in this country. Previous to this it was known to occur only in Australia, Japan and India. It has been found in the United States only in one place, namely, Madison county, Illinois.

The government has established strict quarantines in an effort to prevent the further spread of the disease and the strongest efforts are being made to completely eradicate it. Seed treatment combined with crop rotation as recommended for flag smut of rye should effectively control flag smut of wheat. All seed wheat should be treated before planting as a precaution in preventing its introduction into new areas. Should flag smut of wheat be discovered in Colorado it should be immediately reported to the Agricultural College.

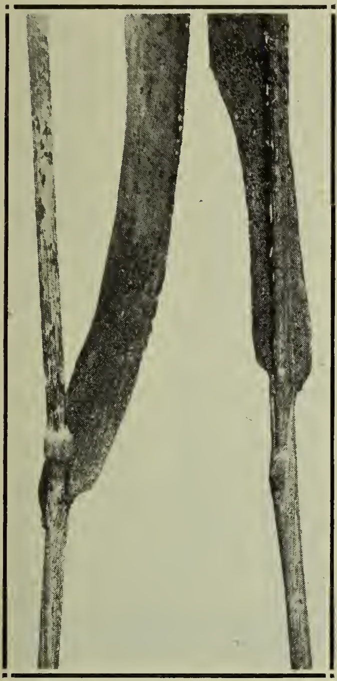
RUSTS

The rusts of cereals are too well known to require much description. In destructiveness they rank second only to the smuts. In some years the loss even exceeds that caused by the smuts. In 1916 it is estimated that the black stem rust alone destroyed at least 280,000,000 bushels of wheat in Canada and the United States. To this must be added the loss of oats, barley, and rye, which ranged from 15 to 25 percent of the crop.

The rusts occur not only on the cultivated cereals but many species of wild grass are also affected. Certain rusts may live also on such plants as the barberry or buckthorn which makes them much harder to control. Each cereal has it own particular rust which will attack no other cereal, but which may affect a number of wild grasses. Each kind of grass may also be attacked by two or three different kinds of rust.

The cereal rusts may be roughly classified into two groups, namely, the leaf rusts that are more commonly found on the leaves and the stem rusts of those found on both stems and leaves. It is the latter group that is responsible for the greatest loss.

Stem Rust of Wheat, Oats, Barley, and Rye (Puccinia graminis)—Each cereal has its own specialized form of stem rust which can affect none of the other cereals. Each form, however, can affect a number of wild grasses. Elongated reddish brown blisters break open and a mass of red rust-colored spores are set free to be blown about by the wind for long distances. When these fall on the proper host under the proper conditions they germinate and produce new rust spots. Later in the season black spores are formed in the rust spots instead of the red spores. These black spores have thick walls and may live over the winter while the red spores have thin walls and survive the winter only in very mild climates. The black spores do not germinate until spring and then can not infect any of the cereals. They do, however, infect the common barberry shrub. On the leaves of the barberry they produce yellowish or orange colored spores. These yellow spores produced on the barberry cannot infect the barberry but are blown back to the cereals and grasses where they again produce the red spores.


Black stem rust of wheat.

The rusts cannot be controlled by any known method of spraying or seed treatment and little success has rewarded efforts to develop resistant varieties. The eradication of the common barberry from which the rust gets its start in the spring gives more promise for success than any other method. Losses from this rust have been successfully avoided in Denmark since 1903 by this measure. The United States Department of Agriculture has underway a campaign to destroy all common barberries in the wheat growing sections of the United States. Many bushes have already been destroyed. Learn to recognize the barberry bush and if you have one on your property destroy it. Write to the Agricultural College for further information.

Leaf Rust of Wheat (Puccinia triticina)—Leaf rust as the name indicates commonly occurs on the leaves and is never as destructive as the stem rust. In severe cases of infection, however, a considerable reduction in yield may result.

Small round orange-red blisters are formed in which are thousands of red spores. These spread the rust from plant to plant and may live from year to year starting the rust anew each spring. Black spores are also formed by leaf rust but no plant is known in this country that they infect. No effective control measures for this rust are known.

Leaf Rust of Barley (Puccinia simplex)—This rust is very similar to the leaf rust of wheat. No effective control measures are known.

Leaf Rust of Rye (Puccinia dispersa)—There is also no essential difference between this rust and the one described above.

Crown Rust of Oats (Puccinia coronata)—This is a rust somewhat intermediate between the leaf and stem rusts. It is found chiefly on the leaves but may also occur abundantly on the stems. It lives one stage of its life on the buckthorn in the same way that the stem rust lives on the barberry. In oat growing sections where the buckthorn is plentiful its destruction would undoubtedly reduce the amount of this rust.

Yellow Stripe Rust of Wheat, Barley and Rye (Puccinia glumarum)—Yellow stripe rust is found on the above three cereals and a number of wild grasses. It never occurs on oats. It seems to be confined to the western part of the United States although it has been found in a few places in Colorado. It often becomes destructive west of the Rocky Mountains.

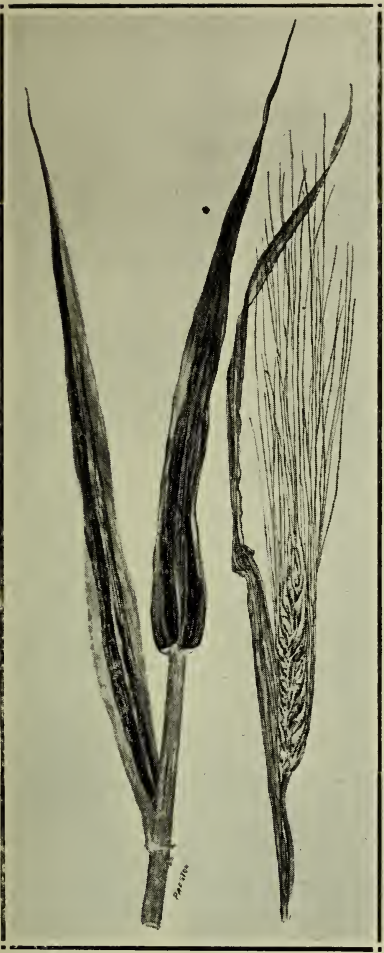
Yellow stripe rust as its name indicates is characterized by the bright yellow stripes formed on the leaves of the affected plants. The yellow stripes and blisters are also quite commonly formed on the inside of the glumes and often on the kernel itself. No successful control measures have yet been worked out.

OTHER CEREAL DISEASES

Barley Stripe (Helminthosporium graminium) (57)—Stripe is a serious disease of barley in Colorado. Fields were observed in 1919 in which as high as 25 per cent of the plants were heavily affected.

Diseased plants show long yellowish to brown stripes on the leaves and stems. The heads are also often affected turning a grayish brown and forming shrivelled grain. In several cases the entire plant may die, usually about the heading time. The spores of the fungus are formed on the surface of the stripes and are scattered to the barley kernels in thrashing. They apparently live over the winter on the kernels.

Experiments carried on at the Wisconsin Experiment Station indicate that stripe may be controlled by treating the seed with formaldehyde, one pint to thirty gallons of water for two hours. After treatment the grain should be dried as rapidly as possible and planted at once or stored in bags that have been disinfected with the formaldehyde solution.

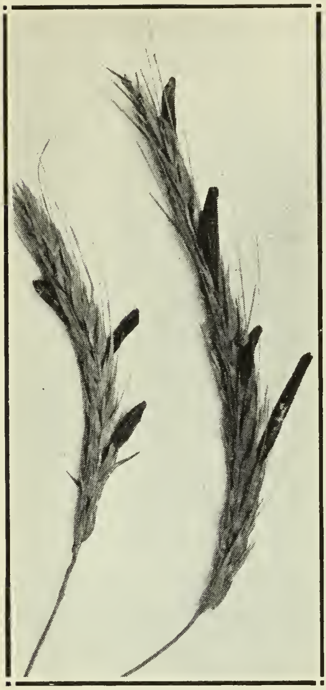


Barley stripe.

Ergot (Claviceps purpurea) (58)—Ergot affects rye, wheat, barley, oats and a number of wild grasses. It is more common, however, on rye and wheat and is not often found on barley and oats.

The kernels of affected plants are replaced by hard black ergot bodies ranging from one-half to an inch or more in length.

Ergot is caused by a fungus which infects the plant while in blossom. The spores fall upon the young ovary, grow into it, replacing the developing kernel with a mass of fungus tissue which becomes the ergot body. The ergot body in the process of development produces spores in great numbers scattered over its surface. These spores are scattered by wind and insects to other flowers and thus spread the disease from plant to plant. When the grain is mature the ergot bodies often fall to the ground where they remain over winter. The following spring when the grain is just beginning to head out the ergot bodies germinate by sending up a number of branches to the surface of the soil, each of which produces a quantity of spores on knob like tips. The spores produced in this way start the first infection in the spring.



Ergot of rye.

Since the ergot bodies live over in the soil, rye should not be planted on the same soil two years in succession. All ergot bodies should be separated from seed grain before planting. This is best accomplished by a process known as "salting." The principle of this process lies in the fact that the ergot bodies are lighter than normal kernels and will float in a solution of salt water in which the normal grain will sink. The grain is poured slowly with constant stirring into a barrel of salt water the strength of which should vary with the particular lot of grain. The ergot bodies are skimmed from the top and destroyed. The solution is then drawn off and the grain washed with water to remove the salt, dried and planted. For more specific directions see Part III.

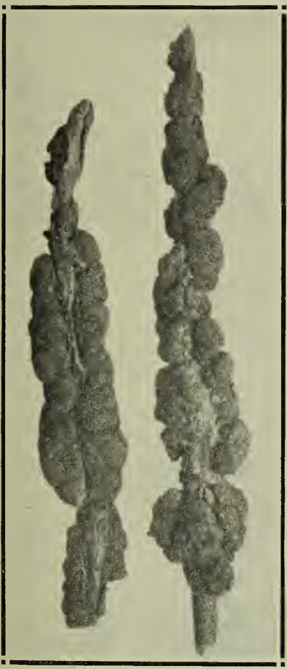
Take-All (53)—A disease of uncertain cause which closely resembles a serious disease of cereals common in Europe and Australia has been recently discovered in the United States. It was found in close association with the flag smut of wheat which fact adds strongly to the evidence that it is the same trouble that is so destructive in the old world. This fact, however, has not yet been definitely established.

In fields but slightly infested small patches of dwarfed plants are found scattered here and there. The plants in these patches if not killed outright take on a characteristic bluish green color. In some fields the infestation may be so severe that practically all the plants are so affected. In such fields many plants are completely killed. The roots become badly rotted and the stems at the surface of the ground turn brown. If affected plants survive early attacks and produce heads no grain is formed and the spikes take on a whitish color. This characteristic gives rise to the name "White head" sometimes applied to the disease.

No effective control measures have yet been worked out. Grain from infested fields should never be used for seed. A rotation keeping any cereals off the land for four or five years should be practiced. Any suspicious cases should be immediately reported to the State Agricultural College.

CHERRY

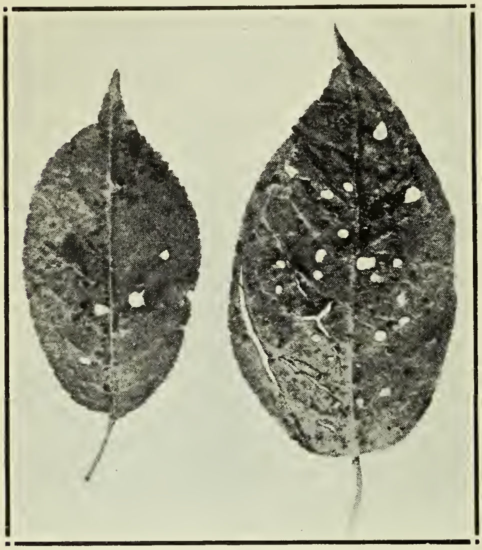
Black Knot (Plowrightia morbosa) (21)—Black knot is common on cherry and plum trees throughout the state. The disease is confined entirely to the woody part of the tree, causing black swollen wart-like knots extending for several inches along twigs and branches. Affected twigs are often bent and twisted or otherwise deformed. The knots are at first soft and cushion like with a velvety surface but turns black, hard and rough with age.



Black knot of plum. (Original in Bulletin 212, by Robbins.)

The knots are due to a fungus which invades the tissues of the branches causing the abnormal growth. The knots are made up partly of fungus growth and partly of deformed tissues of the twig. In the early stages when the knot is soft and cushion like many small spores **(conidia)** are borne over the surface giving it a velvety appearance. Later when the knot become hard, spore cases are formed imbedded in the surface. These spore cases or perithecia contain spore sacks or asci, each ascus containing eight small ascospores. The ascospores protected by the spore cases may easily live over the winter to start the disease again next spring.

Black knot may be controlled by pruning out and destroying all knots as soon as they appear. Wild plums and cherries are also affected and the disease may spread from these. Where it is not practical to eradicate these, spraying with Bordeaux mixture is advised. One application should be made during late winter and another when the buds begin to swell. Other applications may be made if found necessary.



Shot-hole disease of cherry and plum.

Shot-Hole (Cylindrosporium padi) (59)—This leaf spot disease affects not only the leaves but also the fruit. On the leaves small brown spots are formed which often drop out giving rise to the characteristic "shot-hole" appearance. Badly affected leaves usually turn yellow and drop. On the fruit the disease causes small reddish-brown spots. The injury from these spots, however, is usually less than that resulting from loss of leaves.

Spraying with Bordeaux mixture (3-3-50) or lime sulfur (1-40) combined with clean cultivation is said to be effective in controlling the shot-hole disease. The spray should be applied first when petals fall, followed by a later application in about two weeks. It is well to add about one pound of arsenate of lead powder to the spray to control chewing insects. This is also said to add to the effectiveness of the spray.

Brown-Rot (Sclerotinia cinerea) (22), (23)—This is not a common disease in Colorado. It is the same as the brown rot of peach and other stone fruits. See Peach.

CUCUMBER

Bacterial Wilt (Bacillus tracheiphilus)—Bacterial wilt is common in Colorado on cucumber, cantaloupe, squash and other cucurbits. The disease is characterized by a wilting of the leaves and runners. There is no indication of decay or other injury to the roots or stems. The wilting is caused by bacteria which gain entrance into the plant by means of the bites of insects. The bacteria once in the stem multiply rapidly and plug the water tubes thus causing the plant to wilt.

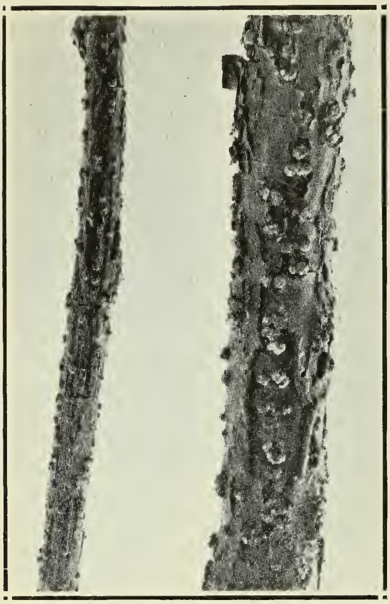
Since the disease is spread by biting insects the best way to control it is by spraying to control such common insects as the squash bug and cucumber beetle. Remove and burn affected plants at once.

Downy Mildew (Plasmopara cubensis)—Downy mildew affects not only the cucumber but all members of the cucumber family such as cantaloupes, watermelson, squash and pumpkins. Affected leaves show irregular yellow spots often covering an entire leaf in which case the leaf shrivels and dies. The oldest leaves are first affected, spreading towards the ends of the vine. A whitish downy fungus growth tinged with purple is often seen on the under side of the leaf. The few cucumbers formed are small and misshapen. Large numbers of spores are formed on the fungus growth, which serve to spread the disease.

Downy mildew may be held in check by spraying with Bordeaux mixture (5-5-50). The first application should be made as soon as the vines begin to run. Later applications should be given at ten day intervals.

Bacterial wilt of cucurbits on squash.

CURRANT



Cane blight of currants and gooseberries.

Canker (Nectria cinnabarina)—A very common disease in Colorado. The first evidence of the disease is a yellowing of the leaves and a premature coloring of the fruit. After the canes are dead, small round pink cushion-like spore masses are formed.

The spores usually enter the plant through wounds but after once gaining foothold it may spread rapidly causing much injury.

Avoid all unnecessary injury to the canes and cut out and burn all diseased canes as soon as they appear. Spraying is not recommended.

White-Pine Blister Rust—see Pine.

FLAX

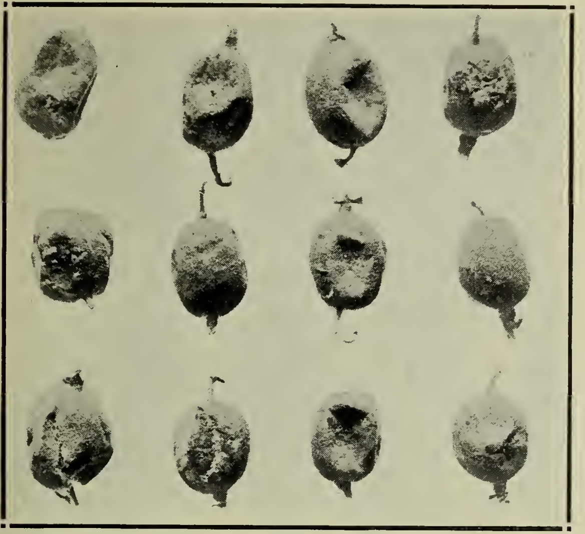
Wilt (Fusarium lini) (60)—Wilt is common where ever flax is grown for two or more years in succession on the same soil. Affected plants turn brown, wilt and die as if from lack of water. Plants may be killed at any stage.

Flax wilt is due to a fungus that lives in the soil from year to year. The fungus penetrates the roots, grows into the water tubes poisoning the plant and cutting off its water supply. The fungus does not occur in new soil but is usually brought in on diseased seed. Since flax is being grown for the first time in many sections of the state it is extremely important that all seed be treated before planting. Use about one-half gallon of dilute formaldehyde, diluted at the rate of one pint to forty gallons of water, to each bushel of grain. Sprinkle the solution and stir the grain at the same time taking pains not to get the seed wet enough to stick together. Allow the seed to stand for several hours covered with canvas. Fan to remove light weight seed and diseased flax straw.

If the soil has once become infected the best procedure is to grow disease resistant strains of flax. Resistant strains may be developed on the farm by selecting seed from the few plants that survive on a badly diseased field. Seed from such plants will show a remarkable degree of resistance. If this selection is continued for several years a highly resistant strain may be developed.

GOOSEBERRY

Mildew (Sphaerotheca mors-uvae) (61)—Mildew is the most serious disease of the gooseberry in Colorado.



Gooseberry mildew on fruit.

A whitish cobwebby growth appears on leaves, stems and fruit turning darker in color late in the season. In severe cases the fruit may be rendered worthless. During the early summer lots of small summer spores are formed on the white cobwebby growth, which aid in scattering the disease from plant to plant. In late summer small black spore cases are developed on the surface of affected parts. These contain spores which on account of the protection of the spore case serve to carry the fungus over winter.

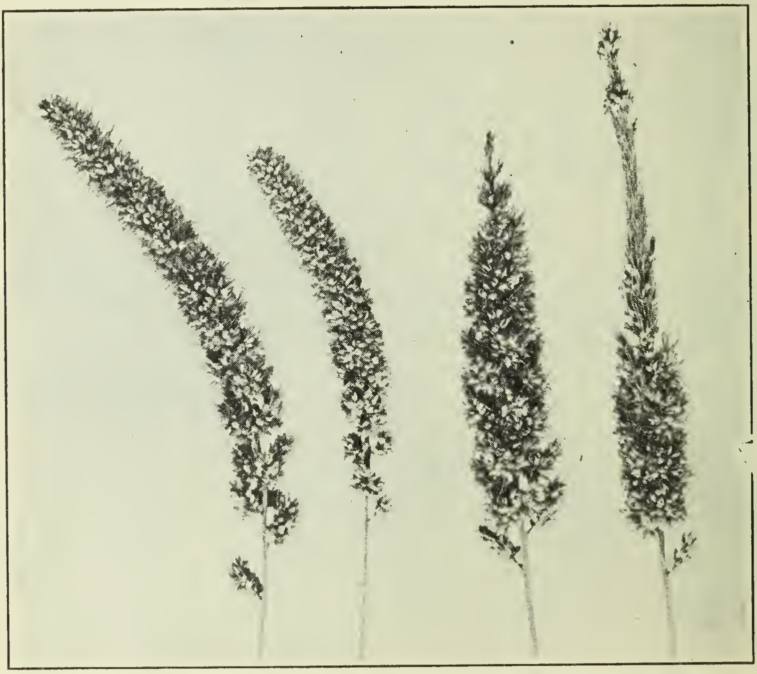
Gooseberry mildew may be held in check by spraying with potassium sulphide, one ounce to two gallons of water. Apply first spray when the buds begin to open. Follow with additional applications at intervals of ten days or two weeks until fruit is ready to pick.

White-Pine Blister Rust—see Pine.

MILLET

Smuts (Ustilago crameri and U. panici-miliacei) (78)—Smut is the most important disease of millet in Colorado. There are two kinds of millet smut. The foxtail millets are affected by **U. crameri.** This fungus replaces the individual kernels with a black mass of spores which is enclosed by the chaff of the grain. The Panicum millets are affected by **U. panici-miliacei,** which replaces the kernels with a black mass of spores but also destroys the chaff. The mass of spores is held together by a thin gray membrane.

Both of these smuts may be controlled by treating the seed with formaldehyde (1-40) in the usual manner for treating wheat.



Millet smut on foxtail millet. (Original in Colorado Experiment Station Bulletin 242, by Vasey.)

PEA

Powdery Mildew (Erysiphe polygoni) (62)—Powdery mildew is common in Colorado on both field and garden peas especially whenever grown late in the season. The usual white cobwebby growth characteristic of mildews is formed. This later turns dark due to the formation of numerous black spore cases large enough to be seen with the naked eye.

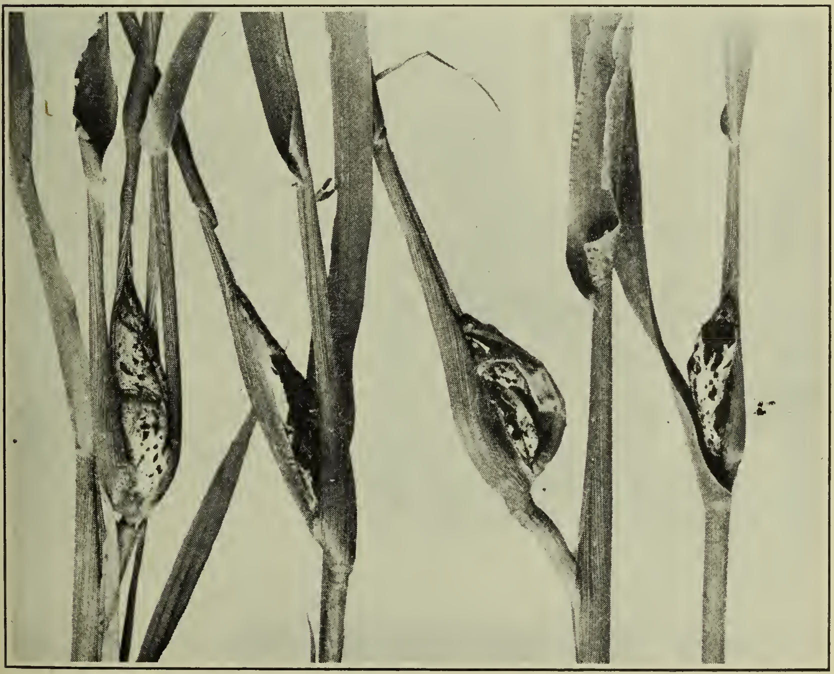
Spraying will control mildew but it is not practical. Plant peas as early in the season as possible and keep soil drained. Use seed from fields known to be free of the disease.

Stem Blight (Pseudomonas pisi) (63)—This is a bacterial disease affecting both field and garden peas. It first made its appearance in 1915 in the San Luis Valley and Northern Colorado where it caused much loss. Since 1919, however, the disease has not occurred in sufficient abundance to produce a great amount of injury.

Stem blight is characterized by a watery olive green to olive brown color of the stems and by yellowish and watery appearing leaflets.

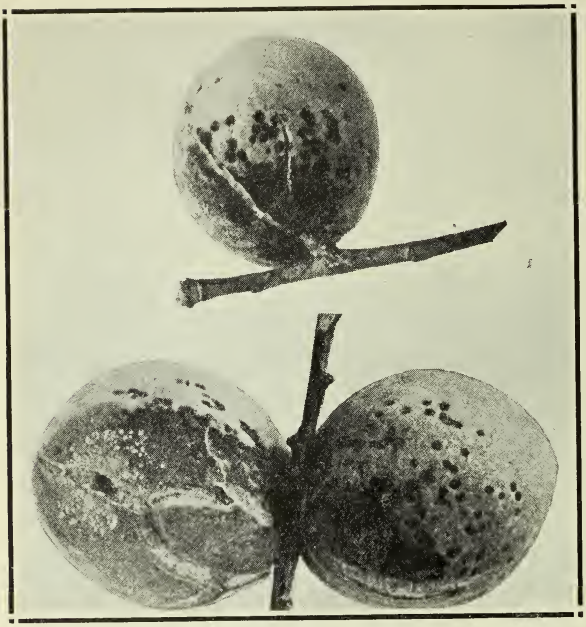
The bacteria causing stem blight gain entrance to the plant through breathing pores or mechanical injuries. Avoid injuring the plant by harrowing or other means of cultivation.

Some varieties of peas are more resistant than others and if the disease again becomes abundant it would be well to select the most resistant kinds. Late planting is also said to reduce the amount of the disease.



Millet smut on proso millet. (Original in Colorado Experiment Station Bulletin 242, by Vasey.)

PEACH



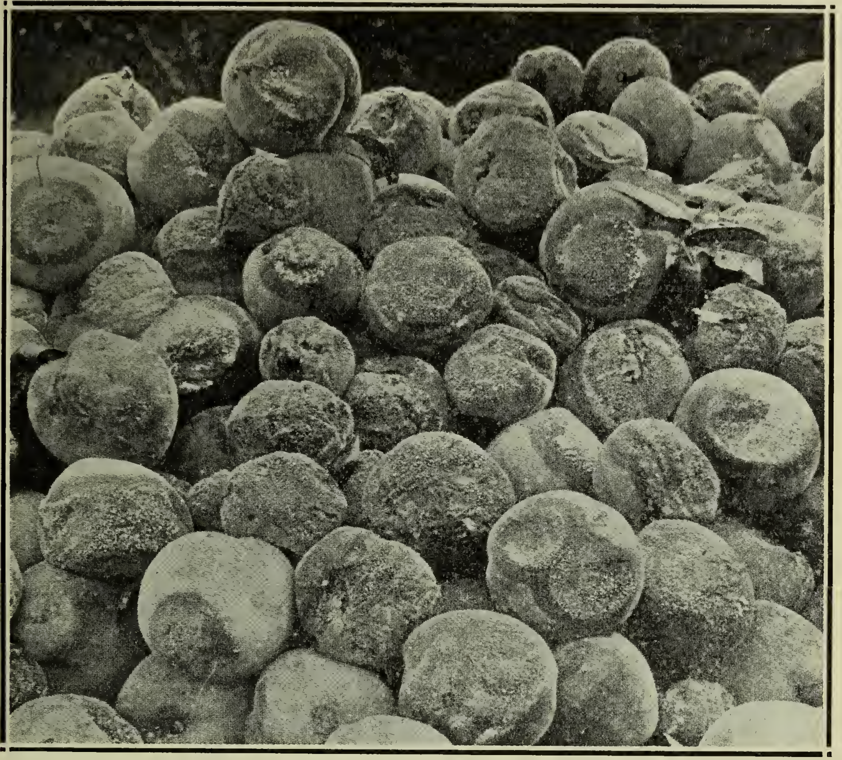
Peach scab. (After Keitt.)

Scab (Cladosporium corpophilum) (64)—Scab is one of the worst diseases of the peach. It affects the fruit, twigs and leaves. It makes its first appearance about four weeks after the petals fall or shortly before the ripening period. On the fruit small round greenish brown spots are formed. These never extend very deep into the flesh. The small spots may run together and form irregular blotches. In severe cases the fruit is often cracked because the diseased skin does not expand to accommodate the growth of the fruit.

Scab may be controlled by spraying with self boiled lime sulfur (8-8-50). For early varieties only one spray is necessary. This should be applied one month after the petals fall. For later varieties two sprays are required, the second about three or four weeks after the first. The lime sulfur may be combined with arsenate sprays used to control insects.

Brown Rot (Sclerotinia cinerea) (22), (23)—Brown rot is perhaps the most destructive disease of the peach, but at present it is not known to occur in Colorado. Since it may be introduced at any time a description is given here.

Brown rot affects all stone fruits including plum, apricot, cherry, and almond. The greatest damage is done on the fruit although the blossoms and twigs may also be affected. On the fruit small brown spots are first formed, these rapidly enlarge until the entire peach is decayed. Whitish tufts of spores are soon formed over the



Brown rot of peach. (After Scott and Ayres.)

surface of the spots. These spores seem to spread the disease from place to place. Spores often fall on ripe fruit causing a decay after the fruit is packed and shipped. The fungus passes the winter in dead and decayed peaches often called "mummies." Hot moist weather is favorable to the development of the disease.

Brown rot may be controlled by spraying with self boiled lime-sulfur first about seven or eight weeks before the fruit is expected to ripen, and by making a second application about one month before the fruit is ripe.

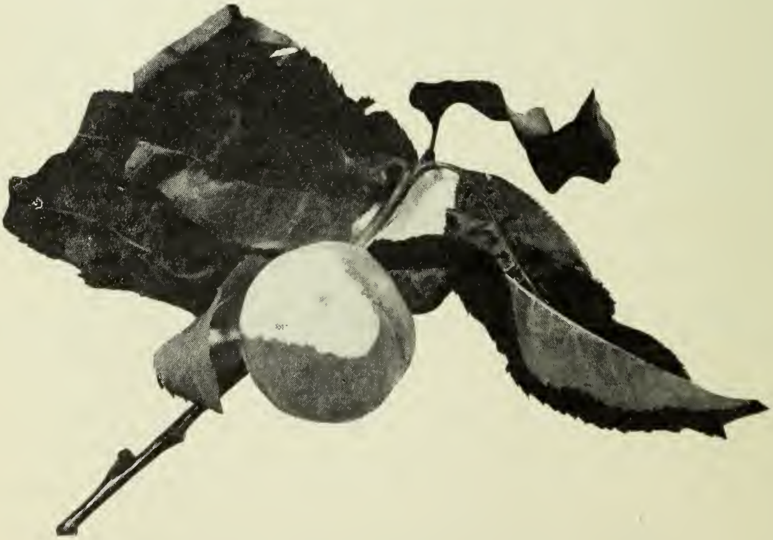
Blight or Fruit-Spot (Coryneum beyerinckii) (24), (25)—This disease occurs in Colorado on peaches and apricots. The fruit leaves and stems are affected. Young buds on the fruiting wood are frequently killed. The green twigs are spotted and the young leaves and fruit drop. Injury is commonly accompanied by the formation of gum about the wounds. Gumming is very common in wet seasons. In badly infected orchards almost the entire crop of fruit may be destroyed. The fruit that survives in such cases is so badly spotted that its market value is greatly lessened. On the leaves irregular reddish brown spots are formed which may fall out causing a shot-hole appearance.

Blight is caused by a fungus that grows in the tissues of the tender twigs, leaves and fruit. Spores are formed in the spots, which when blown about by wind, are means of spreading the disease. The fungus lives over the winter on infected twigs. Spores are produced until late in the fall. The most destructive infection takes place during the months of December and January when the fungus grows directly into the developing buds.

Blight may be controlled by spraying with Bordeaux (5-5-50) in the fall not later than December 15. A second application should be made in the early spring just before buds open.

Mildew (Sphareotheca pannosa) (65)—Mildew is a common disease of the peach in Colorado. The leaves, twigs and fruit are attacked. Irregular white powdery blotches are formed causing the leaves to curl and crinkle and the bark of the twigs to turn brown and dry. Similar white blotches are found on the fruit, checking its development and causing the flesh to become dry and hard.

To control mildew spray with lime sulfur solution or dust with flowers of sulfur. A close watch should be kept for the first appearance of the fungus, when the first application should be made. Later applications should be made at intervals of ten days or as often as necessary.



Powdery mildew of peach. (Original in Bulletin 107, by Whipple.)

PEAR

Fire Blight (Bacillus amylovorus) (4), (5), (6)—This is without doubt the most destructive disease of the pear and is very prevalent in Colorado. Fire blight also affects the apple and quince and sometimes the apricot and plum. Any part of the tree above ground may be affected. It becomes evident in the spring as soon as growth is started but seldom attracts attention until two or three weeks after the blossoming period. The twigs and fruit spurs shrivel, turn brown and then black, giving the appearance of having been burnt. Blight spreads down the twigs affecting the larger branches on which are produced dark sunken cankers. The entire tree is often killed. Fire blight is caused by bacteria which live in the growing soft tissues of affected plants. They are spread chiefly by insects and may enter the plant through insect bites or other wounds.

The bacteria live over the winter in affected tissues of the larger limbs. Such places are called ''hold over'' cankers. In the spring when the sap rises the bacteria become active and drops of clear sticky fluid flow from the cracks in the canker. These drops of ooze are full of bacteria which are scattered by insects and other agencies to healthy twigs.

Fire blight is a very difficult disease to control. It can be held in check by cutting out in the fall diseased branches which might be a source of infection the following spring. Cankers which occur in crotches should be scraped down to healthy wood and disinfected with corrosive sublimate. All blighted twigs should be pruned out and destroyed as soon as they appear in the spring. Such twigs should be cut several inches below the blackened tissues. The pruning knife should be disinfected between each operation by dipping into a solution of corrosive sublimate (1-1000).

Crown Gall—see Apple.

Rust—see Apple.

PINE

White Pine Blister Rust (Cronartium ribicola) (66)—This is an extremely destructive disease of all five-needle pines. It is a native of Europe but was introduced into this country a little over ten years ago. Since that time it has practically destroyed all the white pines of the Eastern states. It has been spreading slowly westward and a few years ago it was discovered in Western Minnesota. There

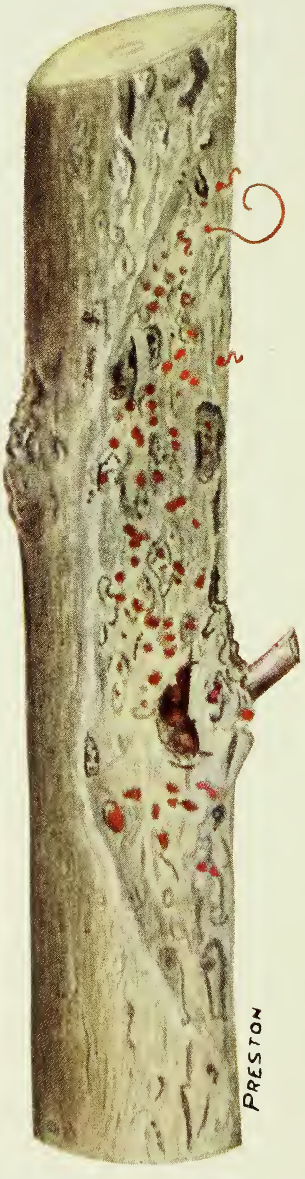
White pine blister rust. (After Stewart and Rankin.)

is great danger of its being introduced into the Rocky Mountain forests at any time. The United States Department of Agriculture is spending great sums of money in an effort to prevent its further spread. The native stands of the sugar pine and the Western White pine in the western forests are valued at $240,000,000 Both of these trees are known to be susceptible to the disease. If they once become infected there is little hope of controlling the disease unless it is discovered soon enough to eradicate it before it becomes wide spread.

The disease affects not only the five leaf pines but lives one stage of its life on the wild and cultivated currants and gooseberries. Upon pines in early summer the rust causes irregular swellings in the bark. On the swellings in early summer white blisters are formed which later break open to set free a dust-like mass of bright yellow spores. Affected trees are eventually girdled and completely killed.

The spores formed in the blisters on the pines are blown to currant and gooseberry bushes on the leaves of which they form, first, small yellow spots which also contains spores. These spores spread the disease to other currant or gooseberry bushes. In late summer and autumn a second kind of spore is formed on the currant or gooseberry leaves and are seen as a brown hairy coating on the lower surface of the leaves. These spores cannot infect the gooseberry or currant bushes but are scattered to the pine which they infect, starting the disease anew.

The only practical means of preventing loss from the white pine blister rust is to prevent its introduction into the Western states. Quarantine laws have been passed to prevent the westward shipment of any white pines, gooseberries or currants. Quarantine laws, how-



From Eleventh Annual Report, State Entomologist of Colorado ever, are not always effective. Learn to recognize the disease if you see it and report all suspicious cases to the Agricultural College.

PLUM

Plum Pocket (Taphrina communis) (67)—This is a common and serious disease of the plum in Colorado. Affected fruits first turn yellow followed by a rapid enlargement to several times the normal size. The surface becomes wrinkled and the pit fails to develop being replaced by a large empty cavity. The diseased fruit later turns brown, shrivels and may fall off or remain attached to the tree for some time. The entire crop may be destroyed in this way.

Plum pocket is caused by a fungus which infects the young fruit as soon as it is formed causing it to make the abnormal growth described above. Where and in what condition the spores live over the winter is not definitely known, but it has been demonstrated that the disease can be controlled by spraying with lime sulfur. Either the factory or self boiled solution may be used. Only one application is necessary. It should be applied in late winter or in early spring before the flowers begin to open.

Shot-Hole—see Cherry.

Crown Gall—see Apple.

Black Knot—see Cherry.

POPLAR

Canker (Cytospora chrysosperma) (68)—Various species of poplar and willow are important in Colorado as shade and ornamental trees. In the more arid sections no other tree will make a satisfactory growth. Large numbers of these trees have been killed in the past few years by the canker disease. This is especially true in the southern half of the state.

Canker affects the twigs and large branches of the tree. The most prominent sign of the disease is the red gummy substance that is excreted over the surface of diseased branches in the form of slender thread-like coils or small red dots.

The disease is caused by a fungus that usually infects the plants through wounds of some sort.

Small branches are usually the first to die and the disease spreads rapidly from these down to the main trunk which is eventually girded, killing the entire tree. Shoots or suckers often put up from the ground after the upper part of the tree is killed.

Colored Plate on opposite page illustrates the poplar canker. Original used in Colorado State Entomologist's Annual Report for 1919.

To control the disease take good care of young trees by supplying sufficient moisture and avoiding mechanical injuries. If the tree is already infected it may often be saved by pruning out and destroying all diseased twigs and cankers, and painting over the wounds with shellac or coal tar.

Since the disease is known to occur in nurseries, all nursery stock should be inspected and any diseased stock destroyed.

POTATO

Fusarium Blight (Fusarium spp.) (69), (72)—Fusarium blight is common throughout Colorado, but is especially severe in the Greeley district. It is perhaps the most destructive disease of the potato in the state. It has been estimated that in 1917 there was a loss of 500,000 bushels in Colorado due to this disease.

The disease manifests itself first by a wilting and a rolling of the leaves followed in severe cases by a premature death of the remainder of the plant. On examination of diseased plants, the seed piece is found to be rotted and in later stages the roots and stem may also show signs of decay.

Fusarium blight is caused by fungus which lives in the soil and infects the seed piece and spreads from there into the stem and roots killing or seriously injuring the plant.

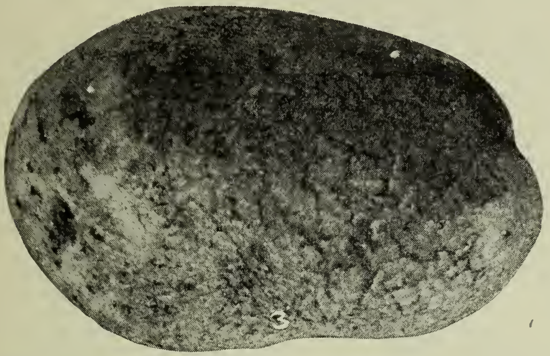
No thoroughly effective methods of control are known but the planting of whole potatoes for seed, combined with judicious irrigation and other cultural practices are perhaps the most effective measures. An excess of moisture should always be avoided. A long rotation raising other crops followed by alfalfa is also very beneficial.

Black Leg (Bacillus atrosepticus) (69), (70), (71), (72)—Black leg occurs in Colorado, but is not responsible for any great loss. The disease occurs on both vines and tubers causing an inky black discoloration near the ground line. The entire plant becomes yellow, wilts, and dies. The seed piece is nearly always rotted. New tubers may often become infected in the field and later develop a soft rot in storage.

Black-leg is caused by bacteria that live from year to year in partly rotted tubers. The organism probably does not live in the soil for a very long time.

A seed piece showing any signs of decay should never be planted. During the growing season all diseased plants should be pulled up and destroyed. All seed should be treated with either formaldehyde or corrosive sublimate as described in Part III.

Dry Stem Rot (Rhizoctonia solani) (69), (70), (72)—This disease, sometimes spoken of as "Rhizoctonia," is often very injurious to the potato. Both tubers and vines are affected. Diseased plants first show a rolling of the leaves with no pronounced wilting. Small aerial tubers may be produced on the stems above ground. Dry reddish brown to black scabs are produced on the tubers.



Rhizoctonia of potato on tubers. (Original in Bulletin 70, by Rolfs.)

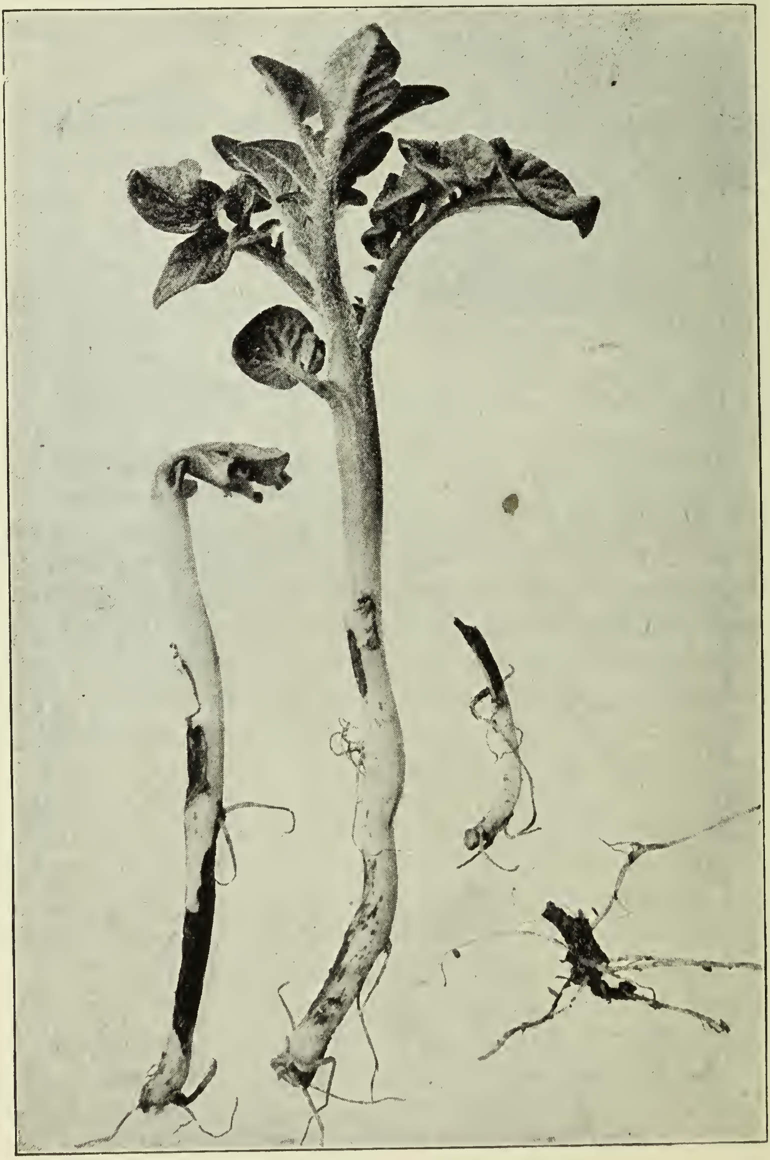
The disease is caused by a common soil fungus and for this reason is difficult to control. The black scabs mentioned above are masses of the fungus and plants from tubers so affected are always seriously injured. See selection, seed treatment with corrosive sublimate, and crop rotation will decrease the amount of the disease.

Scab (Actinomyces scabies) (69), (70), (72), (73)—Scab is common throughout Colorado. Rough, corky, brownish patches are formed over the surface of affected tubers, and the value of the crop is reduced. Scab is caused by a fungus that lives from year to year in the soil or on diseased tubers.

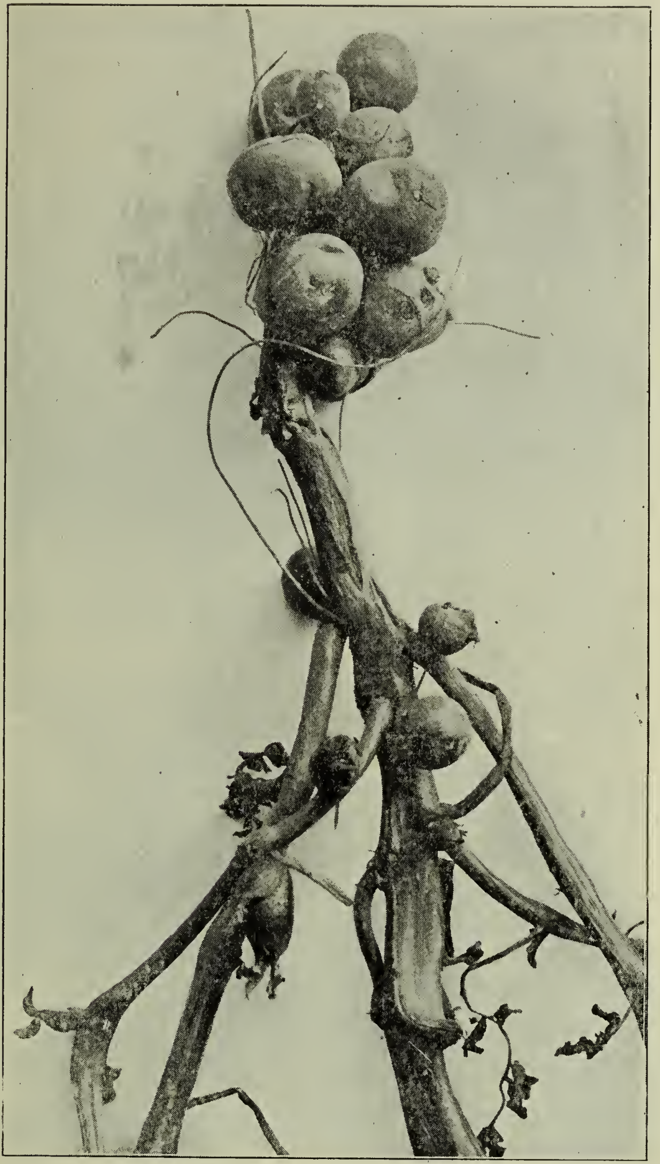
Badly scabbed potatoes should never be used for seed and all seed should be disinfected with either formaldehyde or corrosive sublimate. Alkalinity of the soil increases the amount of scab while acidity decreases it. The addition of wood ashes, lime, and fresh barnyard manure tends to increase the injury from the scab, while plowing under green manure tends to decrease it.

Potato Wart (Chrysophlyctis endobiotica) (74), (75), (76)—Wart is a destructive disease of the potato which was discovered in this country for the first time in 1918. It has long been known as one of the most destructive diseases of the potatoes in Europe. So far it has not been found in Colorado. A close watch should be kept for its appearance in Colorado and any suspected tubers should be sent to the Plant Pathologist, Colorado Agricultural College, Fort Collins, Colorado.

Rough spongy warts are produced on affected tubers. The warts are light brown at first but become black with age. Often all



Rhizoctonia of potato, on stems. (Original in Bulletin 70, by Rolfs.)



Aerial tubers and "little potatoes" formed as a result of infection by Rhizoctonia. (Original in Bulletin 70, by Rolfs.)

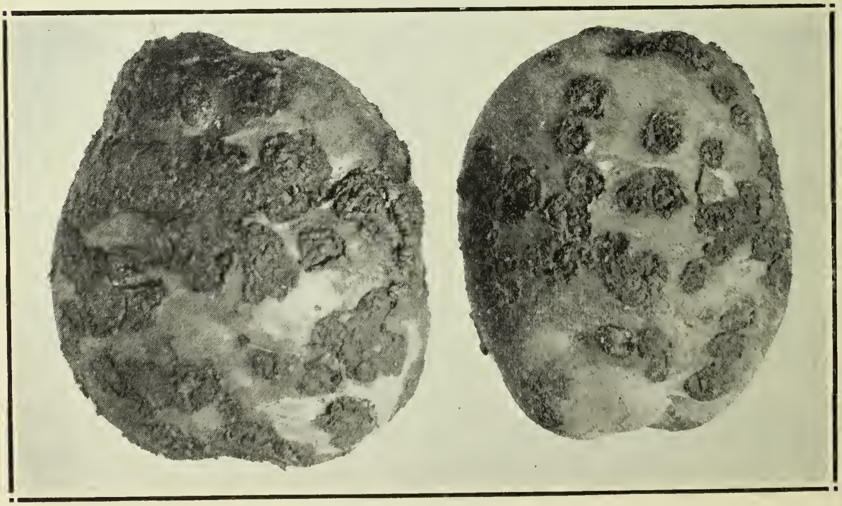
potatoes in a hill are worthless. The disease does not affect the plant above the ground.

The fungus causing potato wart lives from year to year in the soil or on diseased tubers. Crop rotation and the use of resistant varieties offer the best methods of control after the disease has become established.

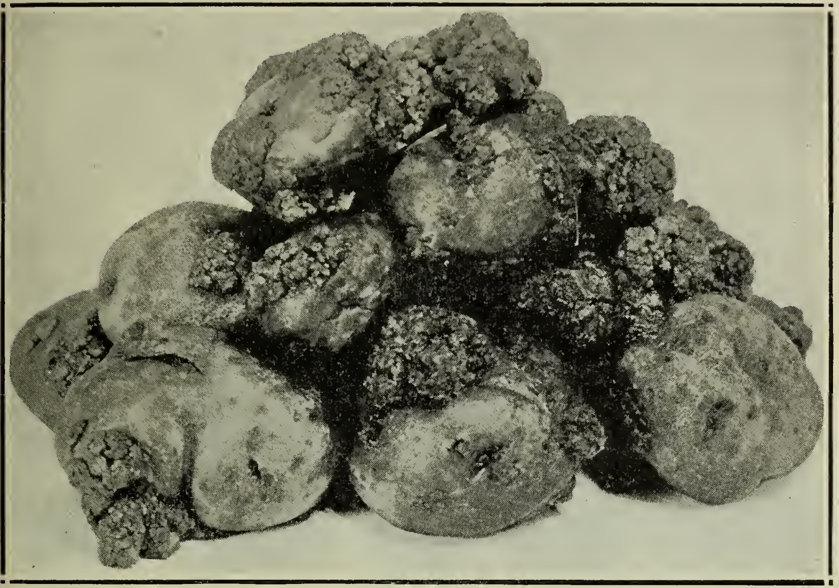
Early Blight (Alternaria solani) (77), (70)—Early blight is a leaf spot disease that is often very prevalent in Colorado. Roundish brown spots marked with concentric rings are produced on affected leaves. The disease seldom causes great loss, but in severe cases some injury is produced. The disease is more severe in moist localities. Early blight may be controlled by spraying with Bordeaux mixture (5-5-50). Spraying should begin early before the blight becomes serious.

Tip-Burn (Hopper-Burn) (70)—This disease which is characterized by a browning and burning of the tip and margins of the leaves is common in Colorado. For many years it was thought to be a physiological disease caused by unfavorable moisture relations. Recent work, however, indicates that an insect, the potato leaf hopper, is largely responsible for the trouble. Probably both factors are involved.

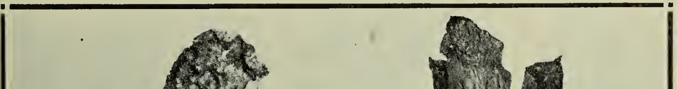
Spraying to control the leaf hopper should reduce the amount of the disease.



Potato scab. (After Stakman and Tolaas.)



Potato wart. (Photograph, courtesy of Plant Disease Survey.)



Early blight of potato. Hopper burn of potato.

RASPBERRY

Anthracnose (Plectodiscella veneta) (79)—This disease occurs also on the blackberry but is more destructive on the raspberry. It is not of great importance in Colorado. Both leaves and the canes are affected, although the greatest injury is to the canes. At first small purplish spots are produced which later increase in size and become grayish white in the center. The margins of the spots may run together and girdle the cane. Affected canes often crack badly. The spots formed on the leaves are similar to those on the canes except that they are smaller. The dead tissue often drops out, giving the leaves a shot-hole effect. Fruit and pedicels may also be attacked.

Diseased canes should be eradicated before the spring season. Clean, healthy plants should be set. Short rotations should be practiced. Spray with Bordeaux mixture (4-4-50) as follows: (1) before the leaves appear, (2) after the leaves are well formed and when the shoots are about six inches high, (3) just before the blossoms appear. If necessary later sprays may be applied at ten day intervals.

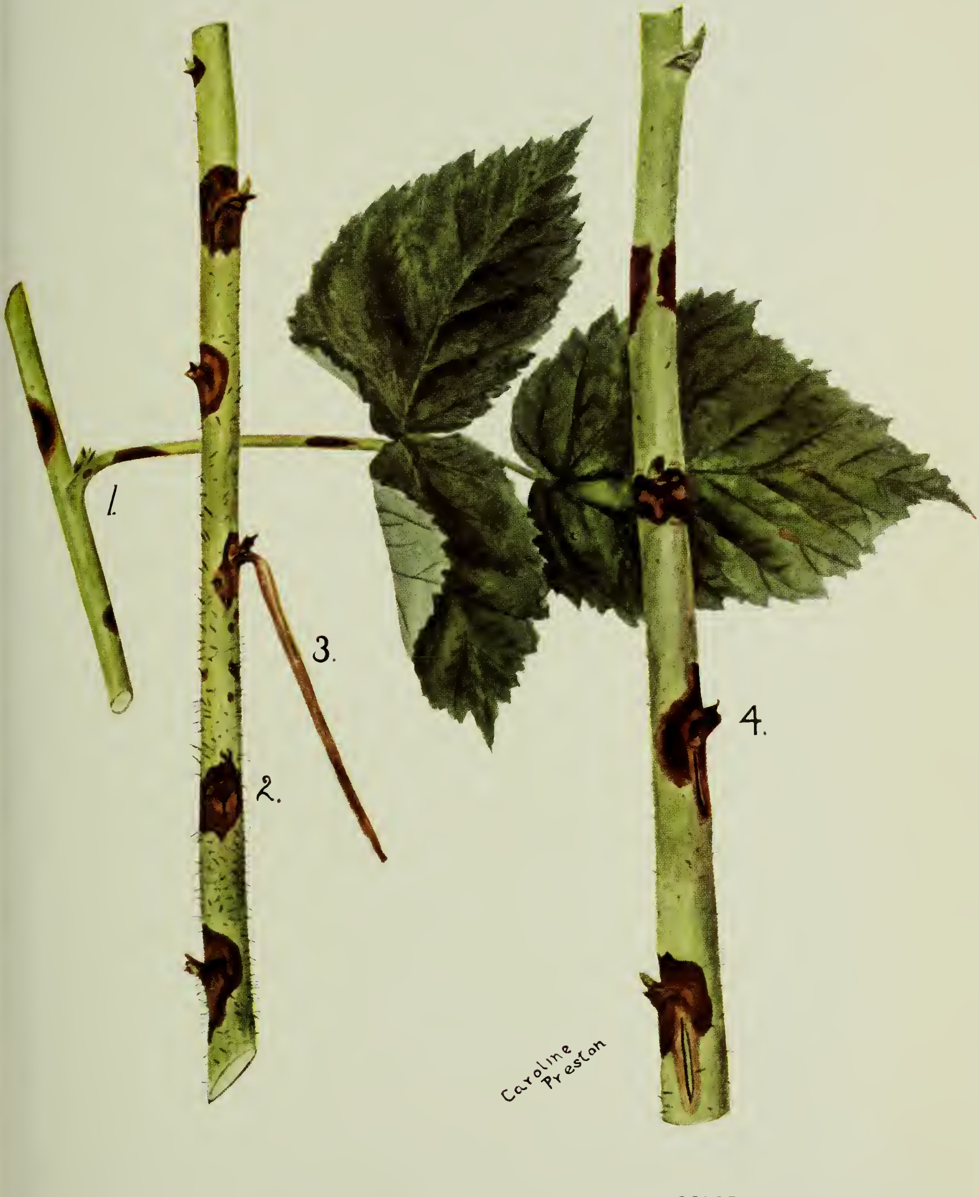
Spur-Blight (Mycosphaerella rubina) (69)—In some years this is a serious disease of the raspberry in Colorado. It reduces the crop by reducing the number of fruit spurs and killing the buds. Diseased canes are extremely brittle and break easily when being put down in the fall or taken up in the spring.

The first symptoms are seen about the first of July. Chocolate brown spots are formed over the lower nodes of the canes and often also along the internodes and on the leaf petioles. The buds from the lower nodes are either killed outright or are so weakened that only poor shoots are produced. No fruit is developed on the lower half of the canes.

Spur-blight may be controlled by spraying with Bordeaux mixture (3-3-50) with two pounds of resin-fish-oil soap added as a sticker. The spray should be applied to the young canes and not to the fruiting canes. Spray (1) about the first of June when the canes are 8-12 inches high, (2) two weeks later, (3) two weeks after the second spray. Remove and burn all old fruiting canes as soon as the berries have been gathered.

Leaf-Spot (Septoria rubi)—Leaf-Spot occurs on raspberries,

The Colored Plate on the opposite page illustrates the spur-blight. Originally used in Bulletin 206, by Sackett.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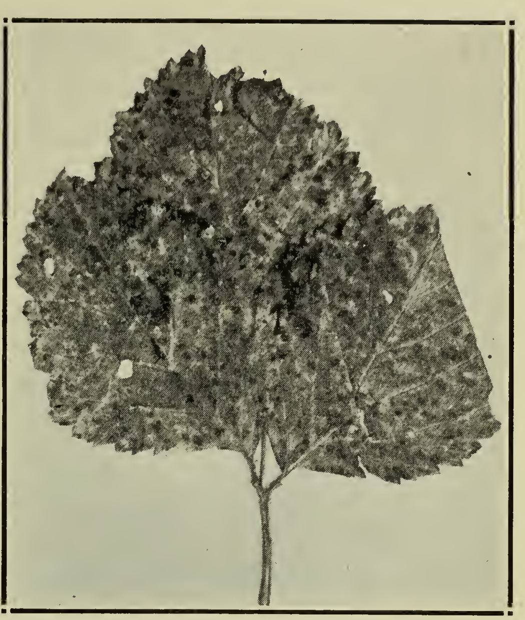
COLORADO AGRL. EXPT. STA.



Leaf spot of dewberry.

blackberries and dewberries being perhaps more severe on the latter. The spots appear about the middle of June as small brown areas. They may become so numerous that an affected leaf will dry up and die.

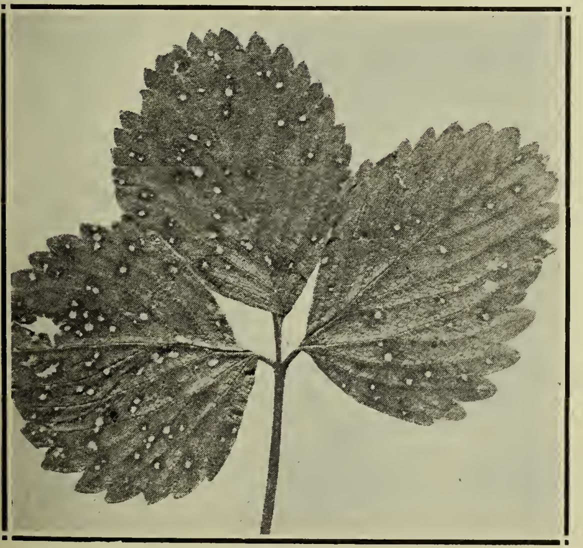
Leaf-spot may be controlled by spraying with either Bordeaux mixture (4-5-50) or lime sulfur (1-50). The first application should be made just after the buds unfold and be followed by later applications at intervals of two or three weeks until the fruit is two-thirds matured.

STRAWBERRY

Leaf-Spot (Mycosphaerella fragariae)—This is the most common strawberry disease. Usually no great injury results from leaf-spot but the loss in certain instances has been very high.

The spots at first are small red or purple dots which rapidly increase in size, becoming whitish gray in the center. The margins remain purple.

Remove and destroy diseased leaves before set-



Leaf spot of strawberry.

ting or use healthy plants. Spray with Bordeaux mixture (4-4-50) before the blossoms open. In case of severe infection mow and burn over the patch just after harvesting. A new set of leaves will be formed free of the disease.

TOMATO

Blight (Fusarium lycopersici) (82), (83)—The first indications of blight is a yellowing of the lower leaves followed by wilting and dying. After a period of time which varies with the weather and the severity of the attack, the entire plant may wilt and die. The woody portions of affected stems are browned. This can easily be detected by pulling off the larger leaves and noting the brownish dots on the leaf scar.

The disease is caused by a fungus that lives from year to year in the soil. Spraying is of no avail. Crop rotation and the use of resistant varieties are the only means of control.

Blossom-End Rot (84), (85)—This is a non-parasitic disease due probably to improper moisture relations. Decay starts usually on half grown tomatoes as a slightly sunken black spot which spreads rapidly until the entire fruit is destroyed.

Spraying has no effect on blossom-end rot. Since dry soil conditions seem to favor the development of the disease, an abundant regular supply of moisture should be maintained.

PART III

PLANT DISEASE CONTROL

General Principles of Control

Every measure that is recommended for the control of a plant disease is based upon a knowledge of the factors which produce it. Every plant disease has a cause. The logical way to control a plant disease is to destroy the cause. If the disease is produced by unfavorable conditions of environment the environment should be modified to suit the needs of the plant. If it is caused by a parasitic organism the organism should be destroyed, or else the plant should be protected against its attack.

A knowledge of the life history of the organism is necessary in order that the measure for destroying the organism or protecting the plant may be applied at the proper time. The conditions which favor the development and spread of the organism should also be known in order that these conditions may be avoided.

In addition to the above, one should be able to recognize a disease in all its stages. It is especially important to be able to detect a disease in its early stages of development in order that control measures may be applied in time to be effective. Many diseases are localized in their distribution but they are constantly spreading to new areas. Too often diseases invade new territory and are not discovered until they become so strongly established that control measures are difficult. One should be able to recognize not only the diseases that are already present, but also those which are liable to be introduced at any time.

All plant disease control measures may be divided into four classes; (1) those based upon the exclusion of a disease from a given area, (2) those which depend upon the eradication of a disease producing organisms in a given area, (3) those involving the protection of plants against a disease producing agent and (4) those based upon the use of disease resistant plants.

Exclusion

Many of the most injurious plant diseases occur only in restricted areas. There are diseases common in Europe which do not occur in this country, and the diseases common in this country do not occur abroad. With the development of commerce and travel, however, these diseases are constantly spreading to new areas and gradually increasing their range.

Within the past eighteen months three new and serious plant diseases have been brought into this country from abroad; namely, the Black Wart of Potato, Flag Smut of Wheat, and Take-All of Wheat, Oats, Barley, and Rye. The White Pine Blister Rust, which has destroyed the White Pine forests of the Eastern States, was brought into this country from abroad. The same is true of the Chestnut Bark Disease which has caused enormous losses in the New England and Middle Atlantic States.

Even in the United States many of our worst diseases occur only in certain sections. Many of the most serious plant diseases have not yet made their appearance in Colorado. There are, however, more diseases in the state at the present time than there were ten, fifteen, or twenty years ago and new ones can be expected to show up in the next few years.

Federal and State quarantines are important means of excluding injurious plant diseases. All nursery stock, seeds and bulbs, that are liable to be infested with injurious parasites are carefully inspected by the government inspectors and if found infested are destroyed. Quarantines are, however, not always effective and every now and then a disease makes its appearance in a new section of the country. For this reason every grower should be on the constant look out for the first appearance of a disease in a new area. The early discovery and immediate suppression of a disease that has just been introduced may mean the saving of thousands of dollars to a community.

Diseases may be brought into a new locality or introduced into clean soil by planting of diseased seeds or seeds that carry the disease on their surface. The planting of seed of unknown origin should be avoided. Any seed that is likely to carry spores of disease producing organisms should be disinfected before planting.

Eradication

Disease control by eradication measures consists of the complete destruction of a disease producing organism in a given area. Eradication measures are most applicable when exclusion measures have failed and a new disease has been discovered before becoming widespread. Eradication methods are best carried out by the State or Government. The Federal and State Governments have united in an effort to eradicate Potato Wart, Flag Smut of Wheat, and Take-

All of Cereals in this country. The White Pine Blister Rust made its appearance in a small isolated area in Northern Minnesota a few years ago. Intensive efforts are now being made to eradicate the disease in that area. The Barberry Eradication Campaign being carried on by the U. S. Department of Agriculture is a good example of eradication on a large scale. Eradication methods may also be used on a small scale in eradicating diseases that have gained entrance into such places as greenhouses, hot beds, etc. Soil sterilization by steam or formaldehyde are the processes usually employed.

Protection

The old adage that "an ounce of prevention is worth a pound of cure," is extremely applicable to plant diseases. Few plants that have once become affected with a disease can be cured by treatment as is the case with men and animals. Plants must be protected from infection by disease producing organisms.

The most practical plant disease control measures come under this head. The common means of protecting plants from the attacks of parasitic organisms are as follows: (1) Good cultural practices, (2) Crop sanitation, (3) Crop rotation, (4) Seed selection and seed treatment, and (5) Spraying.

Good Cultural Practices

There are a large number of disease-producing organisms which can attack plants only when they are in a weak condition. Since proper cultural methods tend to produce healthy, vigorous plants this alone in some cases is adequate protection from the disease. Moreover, certain physiological diseases are produced as a direct result of improper cultural methods. Better cultural practices would, of course, protect the plant against these troubles.

Crop Sanitation

Since most parasitic diseases are spread by the scattering of the causal organism from a diseased to a healthy plant, the removal and destruction of diseased plants or parts of plants is a very important means of protecting the healthy plants. The practicability of this method is, of course, determined by the nature of the disease to be controlled.

Crop Rotation

Many disease-producing organisms live from year to year in the soil but only become sufficiently plentiful to injure the crop when the plant is grown for several years in succession on the same soil.

If a system of rotation is adopted in which the susceptible crop is grown on the same soil not oftener than once in three or four years the organism will die out or at least will not develop in sufficient quantities to seriously injure the crop. There are a number of diseases such as wilts and root rots that can be held in check only by this method. Moreover, a number of disease-producing organisms normally live over the winter on diseased parts of plants that are left scattered over the field. If the crop is planted on the same soil two or more years in succession this diseased rubbish and plant parts will be in the best possible place for starting the disease the second year. Crop rotation involves almost no expense other than a little forethought and planning. The returns in the disease free crops pay for this trouble many times over, not to speak of the added gain in soil fertility.

Seed Selection and Seed Treatment

Selection of clean seed and seed disinfection not only prevent the introduction of disease-producing organisms to new localities but they also act as a protection to the resulting crop. The spores of many parasitic fungi are carried over on the seed and infect the young plant when it begins to grow. Disinfection with certain solutions of proper strength will kill the fungus spores without injuring the seed and the plants produced from such seed are usually free of disease. Solutions of formaldehyde, copper sulfate or corrosive sublimate are commonly used for this purpose. There are other disease-producing organisms however which infect the developing seed and live over inside the tissues of the seed. Ordinary methods of seed disinfection will not kill the organism within the tissues without injuring the seed. For these diseases, therefore, the selection of disease-free seed is the most effective means of control. Seed should be selected in the field from disease free plants because diseased seed often cannot be detected after harvest.

Spraying

This is one of the most common methods of plant disease control. The object of spraying is to keep the surface of the plant covered with a substance that will kill any spores that fall upon it and at the same time will not injure the plant. The spraying must be applied before the spores appear, for, if the spores once gain entrance into the plant, spraying is useless. Spraying should be done before rains and not afterwards, because spores require water for germination and it is at this time that protection is needed. Sprays, when properly made and applied, will not wash off in an average rain, so there should be no worry from this cause.

Bordeaux mixture and lime-sulfur are the two most important sprays used for controlling fungous diseases. Chemicals used for this purpose are commonly called fungicides. Recently, considerable attention has been given to the application of fungicides in the form of powder. This method, although it promises to be of much value, is yet in the experimental stage.

The efficiency of spraying and seed treatment depend largely upon proper preparation of the solution employed. A spray improperly made may not only fail to protect the plant from infection but it may also seriously injure fruit or foliage. Solutions used in seed treatment inaccurately prepared or wrongly used may either fail to kill the fungous spores or it may injure the germination powers of the seed or both. The greatest care should be taken in following directions for mixing and applying both sprays and seed-treatment solutions.

Use of Disease-Resistant Plants

There are a number of varieties of crop plants which on account of some inherent quality are resistant to certain plant diseases. It is obvious that the use of such varieties offers an excellent means of disease control provided the variety is otherwise desirable. Moreover, in the case of many diseases, methods of exclusion, eradication, and protection are ineffective or else impractical. In such cases the use of disease-resistant varieties offers the only means of control. The use of disease-resistant plants not only offers a means of control when other methods fail but whenever such varieties can be obtained it is by far the most effective and inexpensive method.

Disease-resistant varieties have been used with success in combatting a number of serious diseases but so little is known about the true nature of disease-resistance that the work of producing disease-resistant plants has progressed rather slowly. Often existing varieties may show a high degree of resistance to certain diseases but at the same time lack other characters necessary to make it a profitable commercial variety. Such resistant varieties may also not be adapted to the particular region in which the disease is most destructive. In such cases resistant varieties possessing the desirable commercial characteristics have been produced by crossing with other varieties.

It has been possible in certain cases to produce disease-resistant varieties from any given variety by selecting resistant individuals from heavily diseased fields. It was by this method that wilt-resistant flax, blight-resistant tomatoes, and varieties of cabbage resistant to yellows were produced.

The production of disease-resistant plants is a slow, difficult and expensive task and is one that must, for the most part, be left to the Experimental Stations.

PREPARATION AND APPLICATION OF SPRAYS AND OTHER FUNGICIDES

Bordeaux Mixture

This is one of the oldest and best known fungicides. It is perhaps the most valuable spray known for the control of plant diseases. Bordeaux mixture is prepared by mixing a solution of copper-sulfate (blue vitriol) with a solution of stone lime slaked in water. For example, Bordeaux mixture (4-5-50) means that 4 pounds of copper-sulfate and 5 pounds of lime are used to 50 gallons of water. The quality of Bordeaux mixture depends greatly upon the manner in which it is prepared. Bordeaux mixture improperly prepared is worthless. The copper-sulfate and the lime must be dissolved separately and mixed just before using. After the two solutions are mixed they should be used at once, as Bordeaux mixture loses its strength in a very short time. Stock solutions may be prepared by dissolving each ingredient in a small quantity of water. These solutions should be diluted to the proper strength and mixed when ready for use. The following directions may serve as a guide for the preparation of 50 gallons of (4-5-50) Bordeaux mixture.

The quantities of material may vary with the strength and quantity of solution desired.

Materials:

Copper-sulfate (bluestone)	4 pounds
Stone lime	5 pounds
Water	50 gallons

Apparatus:

2 half-barrel tubs with capacity of about 30 gallons, made by sawing a 60-gallon barrel through the middle.
1 60-gallon mixing barrel.
2 or more wooden pails.
1 strong paddle about 6 feet long for stirring the mixture.
1 pair of hand scales for weighing materials.
1 strainer of cloth or 20 mesh brass gauze.

Preparation:

1. Dissolve 4 pounds of copper-sulfate in 25 gallons of water by suspending the copper sulfate in a cloth bag in such a way that the bag will be just under the surface of the water in one of the 30-gallon tubs.
2. Slake 5 pounds of stone lime in the other tub and add water to make 25 gallons.
3. When the solutions are thoroughly dissolved they should be mixed by having one man dip up a pail of copper-sulfate solution and pour it into the 60-gallon barrel, through a cloth suspended over the top, at the same time that another man is pouring in a pail of the lime solution. This process should be continued until the amount of spray desired is mixed. Remove the cloth from the top of the barrel and stir vigorously.
4. Strain the mixture again when filling the spray tank. Use as soon as mixed.

Making Bordeaux mixture. (Original in Bulletin 206, by Sackett.)

Stock Solution of Bordeaux Mixture

When spraying is to be done on a large scale it may be advisable to make stock solutions of the copper-sulfate and lime. Stock solutions are made as follows:

1. Dissolve the required amount of copper-sulfate in water at the rate of 1 pound to 1 gallon. The bluestone should be suspended in a cloth sack beneath the surface of the water where it will dissolve in a few hours.
2. Slake the required amount of stone lime and add water enough to make one gallon to each pound of lime.

These solutions will keep indefinitely. They should be kept in closed containers to prevent loss of water by evaporation. To make Bordeaux mixture from stock solutions dilute to the necessary strength and mix in the usual way. For example (4-5-50) Bordeaux mixture is prepared from stock solutions as follows:

1. Stir stock solution thoroughly.
2. Dilute 4 gallons of stock solution of copper sulfate to make 25 gallons.
3. Dilute 5 gallons of stock solution of lime to make 25 gallons.
4. Mix these two solutions in the manner given above.

Precaution—Only wooden or earthen vessels should be used to contain the copper-sulfate solution or the Bordeaux mixture for they will corrode metal.

Bordeaux Mixture and Resin-Fish-Oil Soap

In spraying Asparagus and other plants with a glossy foliage it is often necessary to add a substance known as a "sticker" in order that the spray adheres. This is accomplished by adding resin-fish-oil soap to ordinary Bordeaux mixture.

1. Dissolve 2 pounds of resin-fish-oil soap in 2 gallons of water.
2. After the copper-sulfate and lime solution have been mixed, add 2 gallons of soap solution to 50 gallons of Bordeaux mixture.

Self-Boiled Lime Sulfur

Some plants, especially stone fruits, are extremely susceptible to injury from Bordeaux spray. For spraying such plants self-boiled lime-sulfur is often used. This spray is prepared as follows:

1. Weigh out 32 pounds of lime and 32 pounds of sulfur. The sulfur should be thoroughly sifted.
2. Place the lime in a barrel and add about 4 gallons of water.
3. Add sulfur as soon as the lime begins to slake. Stir vigorously, adding enough water to make the mixture pasty.

4. Cover the barrel to retain the heat and let stand for five to ten minutes.
5. Add at least 25 gallons of cold water with vigorous stirring as soon as the lime is thoroughly slaked. It is important to cool the preparation as soon as the lime is completely slaked.
6. Dilute to 20 gallons or keep as a stock solution and dilute in proportions as needed.
7. Strain through a cloth or 20-mesh wire gauze before putting into the spray tank.

Both lime-sulfur and Bordeaux mixture as well as any other spray should be applied with a good pressure spray pump. A nozzle that will break the spray into a fine mist is necessary. Good spray pumps of many sizes and types can be bought on the market to suit the purpose of any grower.

Commercial Lime-Sulfur

Commercial lime-sulfur is another valuable fungicide, especially as a dormant spray. This spray differs from the self-boiled lime sulfur in that it is boiled over a fire instead of by the heat of the slacking lime. It usually is prepared in the factories in concentrated solutions. Buy the concentrated mixture and dilute according to directions supplied by the manufacturers.

Ammoniacal Copper Carbonate

This is a spray that is often used late in the season when it is desired not to spot the fruit or foliage with Bordeaux mixture. The spray is prepared as follows:

1. Add enough water to 5 ounces of copper carbonate to make a thin paste.
2. Dissolve the paste in three pints of ammonia diluted with 2 gallons of water.
3. Add water to make 45 gallons.

Flowers of Sulfur

The application of flowers of sulfur is recommended for the control of many diseases, especially the powdery mildews. The sulfur is applied in the form of fine dust. It may be applied on a small scale by dusting from a pepper box, but when applied extensively a special form of bellow-blowers should be used.

Formaldehyde

This fungicide is used chiefly for seed disinfection. The solution can be purchased in strengths approximating 40%. One pint of

40% formaldehyde diluted to 40 gallons is the usual formula although in special cases different proportions are used. The length of the treatment varies with the seed treated. Use as directed for the particular disease and crop.

There are three standard methods of treating grain with formaldehyde. Twenty years of use have shown these to be efficient and reliable. These are: (1) The soaking method, (2) The open tank method, and (3) The sprinkling method. Directions for the use of each of these methods are given below. Select the method best adapted to your conditions and equipment and then follow the directions carefully.

THE SOAKING METHOD

1. Estimate the amount of seed to be treated and purchase formaldehyde (40 per cent strength) one pint for 40 bushels of grain.
2. Clean the seed thoroughly by fanning so as to remove all unbroken smut balls.
3. Dilute the formaldehyde at the rate of one pint to 40 gallons of water.
4. Put a sufficient amount of the diluted solution into a barrel or tank to immerse one or more sacks of seed.
5. Put seed in gunny sacks and immerse in solution. Do not fill the sacks too full; allow room for agitation of the grain so that each seed will become thoroughly wet.
6. Leave the seed in the solution length of time specified in Table I.
7. Remove the sacks and drain, allowing the excess solution to run back into the barrel or tank. Replenish the solution when it gets too low.
8. Leave the treated grain in the wet sacks for not less than six hours nor more than 12 hours. Place the sacks where they will drain rapidly.
9. Plant immediately or empty the grain and spread out in a thin layer to dry. Drying may be facilitated by frequent shoveling.

THE OPEN TANK METHOD

1. Make the formaldehyde solution the same as for the soaking method.
2. Pour the loose grain slowly into the solution in an open vessel. Stir thoroughly and skim off the smut balls.
3. Soak for length of time specified in Table I.
4. Remove the grain, pile, and cover with wet sacks or canvas for not less than six hours and no more than 12 hours.

THE SPRINKLING METHOD

1. Clean the seed thoroughly by fanning so as to remove all unbroken smut balls.
2. Use a clean floor, wagon-bed, or canvas in the open.
3. Spread out a few bushels of grain. Make the formaldehyde solution the same as for the soaking method, and sprinkle it over the grain as it is being shoveled around.
4. Sprinkle at the rate of one gallon of diluted formaldehyde solution to one bushel of grain. A garden sprinkling can may well be used.
5. After all the grain is treated, pile and cover with disinfected sacking or canvas for from 6 to 12 hours.

TABLE I

Use Formaldehyde of Commercial 40 Percent Strength

Grain	Kind of Smut	Proportion of Formaldehyde to Water Mixed	How Long to Soak in Solution
Wheat	Bunt of Stinking Smut	1 pt. to 40 gals.	10-20 minutes
Barley	Closed-Hidden	1 pt. to 40 gals.	10-20 minutes
Oats	All kinds	1 pt. to 40 gals.	10-15 minutes
Millet	All kinds	1 pt. to 40 gals.	40-60 minutes
Rye	Stem Smut	1 pt. to 40 gals.	10-15 minutes
Emmer	Closed	1 pt. to 40 gals.	10-20 minutes
Sorghum	Kernel	1 pt. to 40 gals.	2-4 hours

PRECAUTIONS

Follow directions carefully. Failure to do this may result in the treatment proving ineffective.

Never put treated grain in sacks, barrels, or seeders which have contained untreated seed until they have been disinfected with the formaldehyde solution.

Treated grain may be kept indefinitely if thoroughly dried and protected from further contamination.

If treatment is performed during the winter, care should be taken not to expose the wet grain to frost, as it may result in injury to germination.

All grain should be thoroughly fanned before treating by the soaking or sprinkling methods. If you have not a fanning mill you should use the open tank treatment.

Corn smut, and loose smut of wheat and barley, are not controlled by the above treatments.

Do not use copper sulfate treatment for oats.

When purchasing formaldehyde, look for the standard red label bearing the recommendation of the Colorado Agricultural College. This label furnishes complete directions for seed treatment.

FORMALDEHYDE TREATMENT FOR SEED POTATOES

Soak the seed tubers in formaldehyde solution (1 pint to 30 gallons) for two hours. Either metal or wooden containers may be used. The same solution may be used several times provided it is not left uncovered for any length of time. Pour off the solution and permit the tubers to dry. All containers used to handle the seed after treatment should first be disinfected with the formaldehyde solution. The tubers should be treated before cutting unless they are to be planted immediately. Potatoes treated with formaldehyde may safely be fed to stock if thoroughly washed.

CORROSIVE SUBLIMATE (Poison)

This is a fungicide used chiefly for disinfection of seed potatoes. Four ounces of corrosive sublimate to 30 gallons of water is the usual formula. Dissolve the corrosive sublimate in a gallon or two of hot water and then dilute to 30 gallons. Soak the tubers in this solution for one and one-half hours. Metal containers should never be used. Corrosive sublimate is a violent poison and should be carefully handled. Potatoes treated with this solution should not be fed to stock.

HOT WATER TREATMENT FOR CONTROL OF LOOSE SMUTS OF WHEAT AND BARLEY

Apparatus

1. One accurate and reliable thermometer.
2. Three large barrels, tanks or vats.
3. Several good strong gunny sacks (not canvas).
4. One large boiler in which to heat water.
5. One sprinkling can.

Procedure

1. Heat water in boiler to almost boiling temperature. Pour this into one of the large barrels, tanks or vats and refill boiler. Add cold water and stir with vigor until the temperature is exactly 86 degrees F.

2. Fill the gunny sacks about three-fourths full of grain and tie loosely. Immerse the sacks in the water at 86 degrees F., move up and down several times to expel the air and leave immersed for four hours.

3. After four hours, pour into the second barrel or vat a quantity of nearly boiling water and cool it down by slowly adding cold water with constant stirring until the temperature is exactly 112 degrees F. Refill the heating boiler. Immerse the grain that has

been soaking for four hours into this one, move up and down several times and keep immersed for 15 to 20 minutes.

4. In the meantime, the third barrel should be prepared in a similar manner with water at exactly 129 degrees F. When the grain has been in the second barrel for 15 or 20 minutes remove and place in this barrel with water at 129 degrees F. The temperature of the water will be lowered when the grain is put in. If it falls below 122 degrees F., add a little water from a sprinkling can. The grain should remain in this barrel exactly ten minutes and the water should be kept between 124 degrees F. and 127 degrees F. It should never rise above 129 degrees F.

5. After ten minutes take the bags out and drain them thoroughly. Spread the grain out in a thin layer and allow to dry. The drying process may be speeded up by frequent shoveling over or stirring with a wooden rake. The grain may be planted as soon as dry enough to run freely thru the drill. If it is planted before it is thoroughly dry, the increase in weight from the water absorbed must be compensated for by planting a little more than the usual amount per acre. Care should be taken not to expose the grain to freezing temperature while still wet.

The above treatment when properly carried out will effectively control not only the loose smuts of wheat and barley, but any of the smuts affecting the small grains. On account of the difficulty in applying the treatment it is recommended that only a small lot of grain be treated and that this be planted in a small seed plot isolated as far as possible from other grain fields. The seed produced on such a seed plot should produce plants free of smut.

SALTING METHOD FOR REMOVING ERGOT BODIES FROM RYE

Make a 20 per cent brine solution by dissolving 40 pounds of common salt in 25 gallons of water. Mix the solution in a large barrel, tub or other suitable container. Pour the rye to be cleaned slowly into this solution while another person stirs vigorously. The sound rye kernels will sink to the bottom while the light kernels and ergot bodies will float on the surface. Skim off the ergot bodies and light kernels.

As the specific gravity of grain at different stages of dryness varies slightly, different lots of grain will require different strengths of solution. If the ergot bodies do not float readily, add more salt to the solution. If the sound kernels float, add more water. When all the ergot has been removed, drain off the brine and rinse the grain with fresh water to remove the salt. (If the grain is not rinsed the salt adhering to the seed will injure it during germination.) Spread the cleaned grain on a clean floor and allow to dry. It is then ready for planting.

Since the ergot bodies lose their vitality when grain is stored over winter, this treatment is necessary for seed grain only when it is to be planted the fall after harvest. If the grain is to be used for feeding purposes, however, the ergot must all be removed because it contains a very potent poison.

REFERENCES

Bulletins on Plant Diseases[1]

1. Colo. Agri. Exp. Sta. Bul. 158.
2. U. S. Dept. Agr. Bul. 759.
3. Colo. Agr. Exp. Sta. Bul. 348.
4. Cornell Agr. Exp. Sta. Bul. 236.
5. Cornell Agr. Exp. Sta. Bul. 272.
6. Cornell Agr. Exp. Sta. Bul. 329.
7. Cornell Agr. Exp. Sta. Bul. 335.
8. Cornell Agr. Exp. Sta. Bul. 379.
9. U. S. Dept. Agr. Farmers' Bul. 938.
10. Ill. Agr. Exp. Sta. Bul. 117.
11. W. Va. Agr. Exp. Sta. Bul. 712.
12. U. S. Dept. Agr. Bul. 712.
13. Iowa Agr. Exp. Sta. (Research) Bul. 50.
14. Colo. Agr. Exp. Sta. Bul. 179.
15. Colo. Agr. Exp. Sta. Bul. 235.
16. Colo. Agr. Exp. Sta. Bul. 105.
17. Mont. Agr. Exp. Sta. Bul. 91.
18. Cornell Agr. Exp. Sta. Bul. 382.
19. Cornell Agr. Exp. Sta. Bul. 288.
20. N. Y. Agr. Exp. Sta. Bul. 287.
21. Cornell Agr. Exp. Sta. Bul. 81.
22. U. S. Dept. Agr. Farmers' Bul. 440.
23. U. S. Dept. Agr. B. P. I. Bul. 174.
24. Cal. Agr. Exp. Sta. Bul. 191.
25. Oregon Agr. Exp. Sta. Bul. 106.
26. U. S. Dept. Agr. Bul. 395.
27. N. Y. Agr. Exp. Sta. Bul. 188.
28. Cal. Agr. Exp. Sta. Bul. 172.
29. Cal. Agr. Exp. Sta. Bul. 165.
30. U. S. Dept. Agr. B. P. I. Bul. 263.
31. Colo. Agr. Exp. Sta. Bul. 234.
32. Mich. Agr. Exp. Sta. (Tech.) Bul. 38.
33. La. Agr. Exp. Sta. Bul. 139.
34. Cornell Agr. Exp. Sta. Bul. 255.
35. La. Agr. Exp. Sta. Bul. 119.
36. Va. Agr. Exp. Sta. Bul. 220.
37. U. S. Dept. Agr. Farmers' Bul. 772.
38. U. S. Dept. B. P. I. Bul. 122.
39. U. S. Dept. B. P. I. Bul. 181.
40. U. S. Dept. Agr. Farmers' Bul. 618.
41. Cornell Agr. Exp. Sta. Bul. 395.
42. Western Wash. Agr. Exp. Sta. Bul. 97.
43. Mich. Agr. Exp. Sta. Special Bul. 88.
44. U. S. Dept. Agr. Farmers' Bul. 925.
45. Wis. Agr. Exp. Sta. (Research) Bul. 38.
46. Cornell Agr. Exp. Sta. Bul. 387.
47. Cal. Agr. Exp. Sta. Bul. 208.
48. Dominion of Canada Dept. of Agr. Bul. 73.
49. Colo. Agr. Coll. Ext. Bul. Series 1, No. 117.
50. Colo. Agr. Coll. Ext. Bul. Series 1, No. 159-a.
51. U. S. Dept. Agr. Farmers' Bul. 939.
52. Minn. Agr. Exp. Sta. Bul. 160.
53. U. S. Dept. Agr. Farmers' Bul. 1063.
54. U. S. Dept. Agr. Farmers' Bul. 1058.
55. U. S. Dept. Agr. Year Book, 1918 Separate 796.
56. Colo. Agr. Coll. Ext. Bul. Series 1, No. 155-a.
57. Wis. Agr. Ext. Circular 57.
58. Wis. Agr. Exp. Sta. Circular 94.
59. U. S. Dept. Agr. Farmers' Bul. 1053.
60. N. Dakota Agr. Exp. Sta. Bul. 50.
61. N. Y. Agr. Exp. Sta. (Geneva) Bul. 161.
62. Ohio Agr. Exp. Sta. Bul. 173.
63. Colo. Agr. Exp. Sta. Bul. 218.
64. U. S. Dept. Agr. Bul. 395.
65. Colo. Agr. Exp. Sta. Bul. 107.
66. U. S. Dept. Agr. Farmers' Bul. 724.
67. Montana Agr. Exp. Sta. Bul. 123.
68. Ann. Report Colo. State Entomologist 1919.

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[1] The bulletins included in this list are for the most part non-technical and can be obtained by writing to the Experiment Stations at which they were published.

69. Colo. Agr. College Ext. Bul. Series 1, No. 136.
70. Minn. Agr. Exp. Sta. Bul. 158.
71. U. S. Dept. Agr. Farmers' Bul. 953.
72. Maine Agr. Exp. Sta. Bul. 194.
73. Vermont Agr. Exp. Sta. Bul. 184.
74. U. S. Dept. Agr. Dept. Cir. 32.
75. U. S. Dept. Agr. C. T. and F. C. D. Cir. 6.
76. Penn. Agr. Exp. Sta. Bul. 156.
77. Wis. Agr. Exp. Sta. Research Bul. 42.
78. Colo. Agr. Exp. Sta. Bul. 242.
79. Cornell Agr. Exp. Sta. Bul. 395.
80. Colo. Agr. Exp. Sta. Bul. 206.
81. West Wash. Agr. Exp. Sta. Bul. 97.
82. Wash. Agr. Exp. Sta. Bul. 115.
83. Tenn. Agr. Exp. Sta. Bul. 95.
84. Ga. Agr. Exp. Sta. Bul. 96.
85. Ga. Exp. Sta. Bul. 121.

APPENDIX

Directions for sending in plant disease specimens for identifications:—During the growing season numerous specimens of plant diseases are mailed to the Agricultural College for identification, accompanied by a request for advice on methods of control. The College is willing and glad to render service along this line and in order that the most accurate and reliable information can be supplied we ask that certain important suggestions be carried out in preparing the specimens for mailing. Frequently specimens are received at the College in such poor condition that it is almost impossible to make an accurate determination. If the plant is sufficiently small it is well to include roots, stems, leaves, and fruit when possible as very often one part of a plant may die as a result of an infection on some other part. For example the leaves and fruit may die as a result of an organism attacking the roots or stems. In such cases if only the leaves and fruit were sent it would be impossible to determine the cause of the injury.

Many of the specimens received at the College in poor condition were no doubt in good condition when mailed but it must be remembered that such mail is often on the road two or three days during which time the specimens become dry and brittle before reaching their destination.

Specimens should be wrapped in several thicknesses of moistened newspaper, then covered with several layers of thick wrapping paper or inclosed in a pasteboard box.

Address all specimens to,

The Colorado Experiment Station
State Agricultural College,
Ft. Collins, Colorado.

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Bulletin 260 January, 1921

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

COLORADO WEED SEEDS

By GEO. E. EGGINTON

1879

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1921

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FAMILY KEY

[1]A. Seeds with other parts of the flower adhering, which parts appear as remnants and not as enclosing structures
- Seeds mostly grain-like enclosing in chaffy membraneous scales (bracts).............. 1..GRAMINEAE
- Seeds not grain-like, enclosed in chaffy membraneous scales
  - Seeds circular in outline
    - Seeds with a notched wing; seeds not tightly enclosed in a leaf-like calyx
      - Wing marked with fine radial lines......29..SCROPHULARIACEAE (Linaria)
      - Wing not marked with fine radial lines.... 6..CHENOPODIACEAE (Cycloloma)
    - Seeds not winged; seeds tightly enclosed in a minute leaf-like calyx.............. 6..CHENOPODIACEAE (Chenopodium)
  - Seeds not circular in outline
    - Seeds napiform in outline
      - Seeds usually light brown in color...... 2..CYPERACEAE (Carex)
      - Seeds shiny black to dull black in color.. 5..POLYGONACEAE (Polygonum, not aviculare or convolvulus)
    - Seeds not napiform in outline
      - Seeds triangular in cross-section; russet or red to dull or shiny black in color. 5..[2]POLYGONACEAE (Rumex, Polygonum aviculare and convolvulus)
      - Seeds not triangular in cross-section
        - Seeds bearing a pappus at the apex
          - Pappus long, silky or feathery; seeds nearly circular in cross-section
            - Seeds 8-12 ribbed, smooth.........34..CICHORIACEAE (Lygodesmia)
            - Seeds mostly 10-ribbed, hairy thruout ....33..COMPOSITAE (Laciniaria)
          - Pappus of short, blunt scales or teeth; seeds flattened, truncate
            - Pappus of 1-2 awl-shaped teeth...33..COMPOSITAE (Ratibida)
            - Pappus or numerous (2-3 series) short blunt scales ....34..CICHORIACEAE (Cichorium)
        - Seeds not bearing a pappus
          - Seeds reniform in outline; seeds notched; adhering "scales" ridged ....20..MALVACEAE (Malva, Malvastrum)
          - Seeds not reniform in outline; seeds not notched; adhering scales not ridged
            - Seeds trowel-shaped
              - Seeds enclosed in mealy bracts joined or nearly so at the apex .... 6..CHENOPODIACEAE (Atriplex)
              - Seeds enclosed in hairy bracts not joined at the apex; seed apex terminating in a knob-like projection .... 4..URTICACEAE (Urtica)
            - Seeds not trowel-shaped
              - Seeds irregular in outline (mostly ovate), flattened, roughened, grooved longitudinally...... 6..CHENOPODIACEAE (Kochia)
              - Seeds regular in outline; flat on one side, deeply rounded on the other; embryo spirally coiled .... 6..CHENOPODIACEAE

(Salsola)

A. Seeds without other parts of the flower adhering

B. Seeds armed with spines or prickles, or projections
Spines or prickles barbed
Spines numerous covering the rounded side only ....25..BORAGINACEAE (Lappula)
Spines few; barbs projecting downward from 2-4 spiny awns at the apex......33..COMPOSITAE (Bidens)
Spines or prickles not barbed
Spines or prickles numerous, covering the cylindrical seed, which is 12-18 mm. long ....16..FABACEAE (Franseria)
Spines or prickles few
Spines or prickles slender, sharp, scattered thruout the seed..............32..AMBROSIACEAE (Franseria)
Spines or prickles stout, blunt, arranged in a crown of 5-6 projections at apex ....32..AMBROSIACEAE (Ambrosia)

B. Seeds not armed with spines or prickles

C. Seeds spherical in shape or nearly so
Seeds smooth or only slightly roughened
Seeds mostly black
Hilum a point
Seeds black, 2-2.5 mm. in diameter..10..CARYOPHYLLACEAE (Vaccaria)
Seeds black to deep red, 1-1.8 mm. in diameter ....13..BRASSICACEAE (Brassica, not B. alba)
Hilum a line or scar, usually white or lighter in color than the remainder of the seed........................16..FABACEAE (Vicia)
Seeds not black; seeds yellowish or reddish, irregular or slightly flattened
Seeds grooved........................13..BRASSICACEAE (Brassica alba)
Seeds not grooved....................13..BRASSICACEAE (Raphanus)
Seeds not smooth
Seeds covered with fine, white, bristly hairs ....31..RUBIACEAE (Galium)
Seeds not covered with fine, white, bristly hairs
Seeds black, covered with a network of shallow pits........................12..PAPAVERACEAE (Argemone)
Seeds ash-colored, covered with rough, rounded projections; seeds marked with a seam-like ridge (raphe) on one side............................19..EUPORBIACEAE (Euphorbia)

C. Seeds not spherical in shape

D. Seeds circular in outline
Seeds notched, marked with fine papillose ridges .... 9..ALSINACEAE (Alsine)
Seeds not notched, not marked with fine papillose ridges
Seeds shiny black..................... 7..AMARANTHACEAE (Amaranthus)
Seeds not shiny black
Seeds marked with a large circular scar on the flat side and a network of ridges on the rounded side ....27..LABIATAE (Teucrium)

Seeds not marked with a large circular scar; seeds yellow, dull, granular, rounded on one side, flattened in 2-many planes on the other........................24..CUSCUTACEAE (Cuscuta)

D. Seeds not circular in outline

E. Seeds reniform in shape
Seeds only slightly flattened
Seeds marked with fine branching ridges ....15..ROSACEAE (Potentilla monspeliensis)
Seeds not marked with fine branching ridges
Seeds marked with fine concentric papillose ridges ....10..CARYOPHYLLACEAE (Silene, Lychnis)
Seeds smooth ....10..FABACEAE (Medicago, Psoralea)
Seeds distinctly flattened; seeds marked with fine papillose lines or ridges ....10..CARYOPHYLLACEAE (Saponaria)

E. Seeds not reniform in shape

F. Seeds cordate in shape
Seeds rough, black, marked with distinct knobs projecting from the concentric ridges ....10..CARYOPHYLLACEAE (Agrostemma)
Seeds smooth, or nearly so
Seeds dull-black in color..........20..MALVACEAE (Abutilon)
Seeds not dull-black in color
Seeds yellow in color, shiny, .8-1 mm. long ....16..FABACEAE (Trifolium procumbens)
Seeds grape-green to buff-brown in color, dull, 1.5-2.3 mm. long ....16..FABACEAE (Melilotus)

F. Seeds not cordate in shape

G. Seeds ovate in shape or nearly so
*Seeds flattened on two sides
Seeds with one rounded side and two flat sides meeting in a ridge ....27..LABIATAE (Prunella)
Seeds without a rounded side and two flat sides meeting in a ridge
Seeds shiny black............. 7..AMARANTHACEAE (Amaranthus)
Seeds not shiny black
Seeds dull black
Seeds deeply pitted, wrinkled, margins irregular.28..SOLANACEAE (Solanum rostratum)
Seeds not deeply pitted
Seeds with a minute white scar at the hilum. seeds marked with concentric rows of fine projections... 8..PORTULACACEAE (Portulaca)

Seeds without a white scar at the hilum

Seeds marked with 7-10 broken, white-tipped, transverse ridges ....18..OXALIDACEAE (Oxalis)

Seeds not marked with white-tipped ridges; seeds marked with several concentric ridges converging at the base (hilum)......13..BRASSICACEAE (Thlaspi)

Seeds not dull black

Seeds gray or drab in color, hairy, mottled with **broken** lines or spots.....33..COMPOSITAE (Helianthus)

Seeds not gray or drab in color

Seeds yellow to yellow-red or brown in color

Seeds thin and parchment-like, with a distinct margin ....**23**..ASCLEPIADACEAE (Asclepias)

Seeds not thin and parchment-like

Seeds with one central, longitudinal groove within a loop-like concentric line, both converging at the hilum...13..BRASSICACEAE (Lepidium, not campestre)

Seeds not grooved

Seeds hooked on with a beak; seeds smooth ...11..RANUNCULACEAE (Ranunculus)

Seeds not hooked or beaked; seeds granular, obscurely pitted, crustaceous (hard) ...28..SOLANACEAE (Solanum)

Seeds variable in color, mostly ivory-yellow to drab; seeds with a longitudinal mark or groove

Seeds regular in shape, marginless, roughened with blunt projections which are more distinct on the edges ....14..CAPPARIDACEAE (Cleome)

Seeds irregular in shape, broadly margined, smooth, the sides faceted..21..CACTACEAE (Opuntia)

*Seeds not flattened on two sides; Seeds flattened on one side, rounded on the other; seeds granular, buff to olive in color ....24..CUSCUTACEAE (Cuscuta)

G. Seeds not ovate in shape

H. Seeds flattened

†Seeds flattened on more than two sides

Seeds flattened on three sides; seeds triangular in cross-section .... 5..POLYGONACEAE (Polygonum, Rumex)

Seeds flattened on more than three sides; seeds not triangular in cross-section

Seeds truncate

Seeds prismatic ....22..ONAGRACEAE (Oenothera)

Seeds not prismatic; seeds thimble-shaped, marked with transverse and longitudinal grooves ....29..SCROPHULARIACEAE (Verbascum)

Seeds not truncate; smooth, irregular, with several flat sides................15..ROSACEAE (Rosa)

†Seeds not flattened on more than two sides

††Seeds flattened on two sides

Seeds oblong in shape

Seeds not grooved

Seeds rounded on one side, either truncate or rounded at the apex ....27..LABIATAE (Lycopus, Leonurus, Salvia, Nepeta)

Seeds not rounded on one side

Seeds 1.2-1.5 mm. long with a distinct white margin; seeds smooth......33..COMPOSITAE (Achillea)

Seeds 2-2.5 mm. long; not margined; seeds 6-8 ribbed, rough ....34..CICHORIACEAE (Sonchus)

Seeds grooved
Seeds with two longitudinal grooves on each face; seeds oval in cross-section, .6-.8 mm. long, regular in shape ....13..BRASSICACEAE (Bursa)
Seeds with one distinct longitudinal groove; seeds nearly circular in cross-section, .6-1.3 mm. long, irregular in shape............13..BRASSICACEAE (Sisymbrium)
Seeds not oblong in shape
Seeds wedge-shaped, rounded on one edge, notched on the other; seeds marked with irregular blister-like protuberances .... 9..ALSINACEAE (Cerastium)
Seeds not wedge-shaped
Seeds turbinate in shape, black, shiny......... 1..GRAMINEAE (Panicularia)
Seeds not turbinate in shape
Seeds fusiform in shape
Seeds with a long, slender, hooked tip, hairy at the base ....15..ROSACEAE (Geum)
Seeds without a long, slender, hooked tip
Seeds with a distinct point or beak at the apex; seeds 3-8 veined....34..CICHORIACEAE (Lactuca)
Seeds not pointed or beaked at the apex; seeds truncate; seeds veined or ribbed ....34..CICHORIACEAE (Sonchus)
Seeds not fusiform in shape
Seeds pyriform in shape, 2-3 ribbed or veined.......32..AMBROSIACEAE (Iva ciliata)
Seeds not pyriform in shape
Seeds cuneate in shape ....32..AMBROSIACEAE (Iva)
Seeds narrowly campanulate in shape ....33..COMPOSITAE (Ratibida)

††Seeds flattened on one side; seeds cylindrical to oblong in shape

Seeds with a single groove on each side; seeds 1.5-2.8 long, obscurely flattened, color brown.............13..BRASSICACEAE (Camelina)

Seeds not grooved; seeds dull, granular, yellow in color, distinctly flattened......24..CUSCUTACEAE (Cuscuta)

H. Seeds not flattened

I. Seeds conical in shape

Seeds shiny, stony, pitted, truncate ....25..BORAGINACEAE (Lithospermum)

Seeds dull, smooth, rounded at the apex; seeds with one longitudinal groove on each side ....13..GRASSICACEAE (Lepidium campestre)

I. Seeds not conical in shape

J. Seeds oblong to cylindrical in shape

Seeds not circular in cross-section; seeds obscurely 4-5 angled

Seeds honey-yellow in color ....33..COMPOSITAE (Grindelia)

Seeds usually brown in color ....33..COMPOSITAE (Carduus)

Seeds circular in cross-section thruout

Seeds constricted by two grooves, which form a longitudinal rounded ridge ....13..BRASSICACEAE (Conringia)

Seeds not constricted by two grooves

Seeds reticulated or pitted ....17..GERANIACEAE (Geranium)

Seeds not reticulated or pitted

Seeds distinctly ribbed or ridged longitudinally

Ribs white, usually 10 in number, smooth ....33..COMPOSITAE (Leucanthemum)

Ribs of the same color as the seed, roughened with rounded projections ....33..COMPOSITAE (Anthemis)

Seeds only faintly wrinkled or ribbed

Seeds dull, summit bearing a light-colored disk....33..COMPOSITAE (Artemisia)

Seeds shiny, truncate; apex cup-like with a point in the center...33..COMPOSITAE (Carduus)

J. Seeds not oblong in shape

K. Seeds fusiform in shape, not sircular in cross-section thruout

Seeds smooth or nearly so, 4-8 angled or ribbed at the apex; circular in cross-section at base, somewhat resembling a ten-pin ....22..ONAGRACEAE (Gaura)

Seeds roughened with hard, sharp points near the apex; seeds circular in cross-section at the apex, 4-angled or ribbed at the base.......34..CICHORIACEAE (Taraxacum)

K. Seeds not fusiform in shape

L. Seeds pointed at both ends; seeds cylindrical

Seeds tailed at the ends and often thruout one side; seeds adhering to each other in groups of 4-6.... 3..JUNCACEAE (Juncus)

Seeds not tailed at the ends or on one side

Seeds .4-.6 mm. long, reticulated .... 1..GRAMINEAE (Eragrostis)

Seeds .5-1.5 mm. long, not reticulated; seeds often with black mark at the base .... 1..GRAMINEAE (Sporobolus)

L. Seeds not pointed at both ends

M. Seeds boat-shaped..30..PLANTAGINACEAE (Plantago)

M. Seeds not boat-shaped; seeds trapeziums in outline, frustrums of spherical pyramids in shape............30..PLANTAGINACEAE (Plantago)

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[1] In the KEY TO FAMILIES, "SEEDS" are referred to as such because they are so called in commercial samples. Thus all fruits whether utricles, achenes, caryopses or true seeds are called seeds.

[2] Seeds triangular in cross-section occasionally occur in Polygonum persicaria.

Colorado Weed Seeds

By G. E. EGGINTON

The appearance of weed seeds in lots of field and garden seeds is the rule rather than the exception. It is seldom that commercial seed is free from the seeds of weeds or other crops. However, vegetable and flower seeds, and the seeds of cereals or other crops in breeding plots, when selected, harvested and threshed by hand, are usually free from weed seeds. Occasionally, machine threshed and machine hulled seeds (sorghums and alfalfa more frequently than other crop seeds) are free from weed seeds.

A sample of wheat seed may contain one to many species of weed seeds. For example, in the samples of Colorado wheat examined, there were found 35 species. Wild oats, bindweed, poverty weed, wild buckwheat, cow cockle, kinghead, butterfly-weed, wild sunflower, and wild rose appeared more frequently than others. In the samples of Colorado alfalfa, 72 species of weed seeds were found, those of most common occurrence being black mustard, small-seeded alfalfa dodder, pigweed, lamb's quarters, barnyard grass, gum weed, marsh elder, burning bush, white sweet clover, witchgrass, breadroot, curled dock, Russian thistle, and green foxtail. From the preceding examples cited it would appear that the possibilities of finding absolutely pure seed are extremely limited. Such limited possibilities are further shown by the fact that wheat and alfalfa are among the cleanest of the machine-threshed or machine-hulled crops, with a smaller percentage of impurities and a far less extensive range of weed seed species than any of the common grass crops such as timothy, red top, and blue-grass, or many of the leguminous crops such as red clover, alsike clover, and white clover.

Weed seeds are for the most part disseminated by natural means, yet the introduction of new or foreign species is due to the presence of weed seeds in shipments from other states or countries. Thus foreign weeds may result from the direct planting of crop seeds containing these seeds or by the scattering of weed seeds from grain in transit. In addition to the latter method of dissemination, there are many others which would require extensive space for enumeration.

It is not to be expected, neither is it essential, that a dealer in, or a buyer of, seeds know the number of different sorts of weed seed species that have been found in crop seeds, but it is of value to be able to recognize those weed seeds which occur most frequently or are particularly harmful. For example, the seeds of wild oats, bindweed, wild buckwheat, and cow cockle occur more commonly in wheat and are more harmful and undesirable than the seeds of slender wheat grass or bee plant. A knowledge of the nature of the impurities, then, is of more importance to the purchaser than a statement of the amount (percentum) of the impurities present. For example, one lot of alfalfa seed, 99.2 per cent. pure, contains dodder and wild mustard, another lot, 95 per cent. pure, contains no harmful or undesirable weed seeds, and though inferior in purity to the preceeding lot is of superior quality because of the ***nature*** rather than ***amount*** of the impurities present. Seed of high purity and free from harmful weeds is the most desirable, being an improvement over either of the above possibilities. It is necessary, then, that care be exercised in the selection of all seed though the foregoing cannot be accomplished without a knowledge of what makes for better seed, together with a desire to improve seed quality.

The keys, descriptions, and drawings, included in this bulletin were made that they might be of some assistance in supplying the need for information which is helpful in both buying and selling seeds, particularly field seeds; also that they might be of use for reference or classwork in schools.

The noxious weed seeds designated in the Colorado Seed Act, appear on page 21. Any of these seeds are considered particularly harmful.

It is unnecessary to devote more than a few words to the often quoted and usually misunderstood term "adulteration". In the past seed merchants "adulterated" the seeds they were selling by mixing with them seeds of other species. Thus wild mustard seeds, the germs killed by drying in an oven, were mixed with cabbage, turnip or cauliflower seeds and sold as such. Today "adulteration" has a different meaning, is practiced in a far different way, and is not readily detected. Old seeds that have been in storage for years, or seeds that have been carried over for one or two years, seeds of low vitality, and mechanically injured seeds, all may be mixed proportionately with seeds of the same species having a high germinating power. For example, 50 pounds of Danish ball head cabbage having a vitality of 40 per cent. when mixed thoroughly with 200 pounds of the same variety with a vitality of 95 per cent. would give 250 pounds of cabbage with an average vitality of 84 per cent.

A better understanding of the common impurities and adulterants has created greater interest in better seed, and with it the realization that the best seed is the cheapest after one considers not the initial cost of inferior seed but its damaging effect upon clean fields. Seed may be pure and of good germination but low in quality because of its color. Though color alone should not regulate quality and seed values it is a valuable indicator in that it shows careful harvesting, good hulling, and allows ready detection of foreign seeds.

In buying seed one should keep in mind the following points: Purity, amount and nature of impurities, germination, source of seed, and color. If buying from your neighbor, keep in mind the above points and in addition ask yourself whether or not the seed can be further cleaned by sieves or milling machinery for, though seed companies' stocks are usually cleaned by special machinery your neighbor has no such equipment, neither does he realize the amount and nature of the impurities that may be removed from average lots of seed by even a hand sieve or a small hand mill.

[1]A purity analysis is easily made when there are drawings or samples of weed seeds at hand for comparison. This entire bulletin may be looked thru for a drawing of the seed to be determined, or more easily by first referring to the family key on page 3. After finding the family to which the seed belongs, do the same for the genus and species by referring to the respective keys.

Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 164 were drawn by the author, and the remainder are the work of Miss Caroline M. Preston.

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[1] Colo. Agri. College Bull. 238, "Cleaned, Treated, and Tested Seed".

THE SEED

In Fig. 1 there is shown a diagrammatic section of the pistil of a typical flower after pollination and prior to fertilization. The sepals, petals, and stamens have been removed. The structure we are interested in within this pistil is the ***ovule,*** which develops into the ***seed.*** In the ovaries of some plants, as in the squash for example, there are many ovules and consequently many seeds, whereas, in the ovary of such plants as sunflower, lettuce, buck-

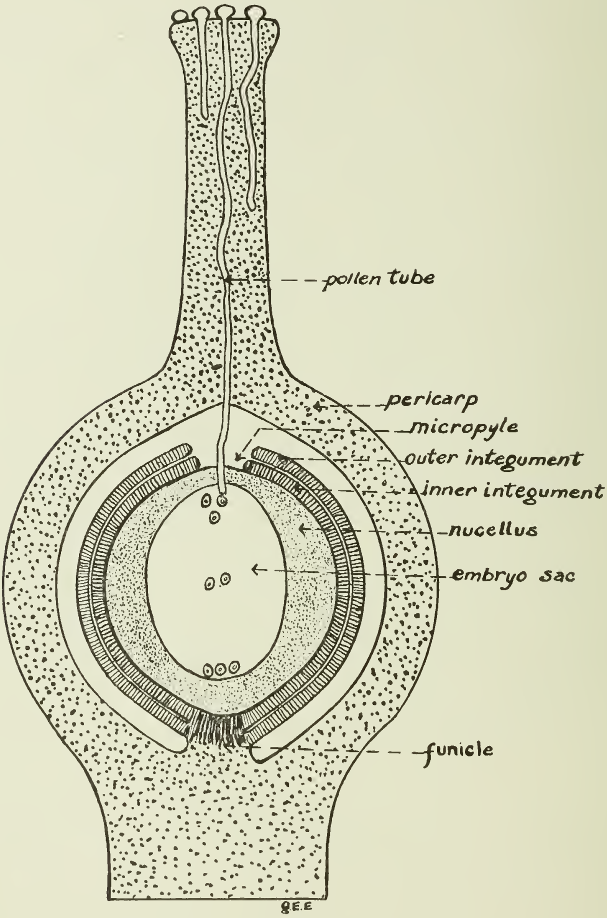
pollen tube
pericarp
micropyle
outer integument
inner integument
nucellus
embryo sac
funicle
GE.E

Fig. 1. Diagrammatic, longitudinal section of a pistil showing embryo sac prior to fertilization. The pollen tube has entered the micropyle, grown through the nucellus and is about to come in contact with the nuclei of the embryo sac.

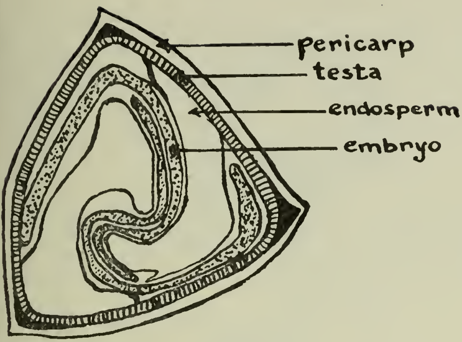

Fig. 2. Cross-section of a buckwheat seed showing the arrangement and position of pericarp, testa, endosperm and embryo. (After Robbins).

wheat, (Fig. 2), wheat, corn, and other cereals, there is but one ovule. Thus we see that the true seed, botanically speaking, is always associated with the flower structure, and is formed within the ovary of the pistil; the seed develops from a structure in the ovary known as the ***ovule.*** In fact, the true ***seed*** may be defined as the fertilized and ripened ***ovule.*** It is primarily a young plant in a resting stage capable of development by germination.

Seed development begins immediately after the union of a male element of the pollen tube with the egg or female element of the ovule. The pollen tube enters the ovule by way of the micropyle. The body resulting from this union of two sexual elements develops into the young plant or ***embryo.*** The embryo may be partly or wholly imbedded in the ***endosperm*** which is a food supply, as in wheat and other cereals, or may occupy the entire space within the seed coats when the endosperm is lacking. The latter condition is characteristic of bean and pumpkin seeds, and is due to the absorption of the endosperm by the embryo during the development of the seed. The cells of the ***nucellus*** are in part absorbed by the developing embroyo and the nucellus is usually present as a thin, compressed layer known as ***perisperm.*** During the process of development of the embryo and nucellus, changes have taken place in the coats of the ovules. The ***integuments,*** or outside layers, have gradually hardened and formed ***seed-coats.***

In describing the kinds of ovules the terms atropous (orthotropous), campylotropous, amphitropous, and anatropous are used (Fig. 3). The same terms may be used in describing seeds, particularly in referring to the relative positions of hilum and micropyle. The seed upon ripening usually detaches itself from the stalk (funicle) and the resulting scar is called the ***hilum.*** The

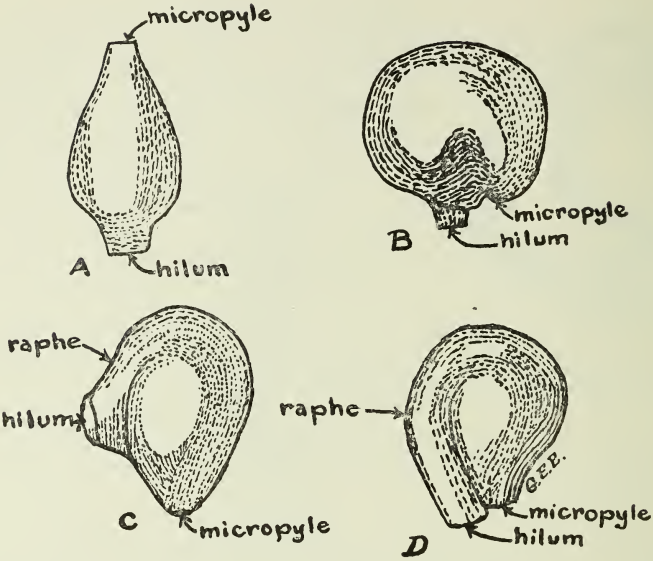
micropyle
A
hilum
B
micropyle
hilum
raphe
hilum
C
micropyle
raphe
G.E.E.
micropyle
hilum
D

Fig. 3. Types of seeds as determined by the relative positions of hilum and micropyle, and the presence or absence of a raphe. A. Atropous (Orthotropous.) B. Campylotropous. C. Amphitropous. D. Anatropous. (After A. Gray.)

opening in the coat of the ovule remains as a tiny, pit-like opening in the seed-coat known as the *micropyle.*

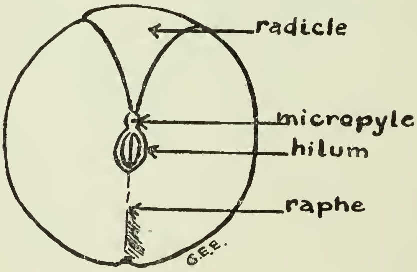
radicle
micropyle
hilum
raphe
G.E.E.

Fig. 4. Pea seed showing external features sometimes referred to in describing seeds.

Seed-coats may vary greatly in their external appearance; they may be ridged, veined, pitted, reticulated, grooved, faceted, scaly and warty, or provided with certain structures such as a *raphe* (Fig. 4). A mature or ripened seed consists of: Embryo, endosperm, nucellus and seed-coats. The embryo (Fig. 5), or young plant, and consequently the most important structure of seed, upon reaching a certain stage in its development becomes dormant for a time, continuing its development only when conditions are again favorable for growth. In a well developed embryo three distinct parts can be found: ***Cotyledons,*** which supply food and in many cases become the first temporary leaves; a ***hypocotyl,*** which terminates in the young root or ***radicle,*** and often pulls the cotyledons and plumule from the seed-coats; and the first bud or ***plumule.***

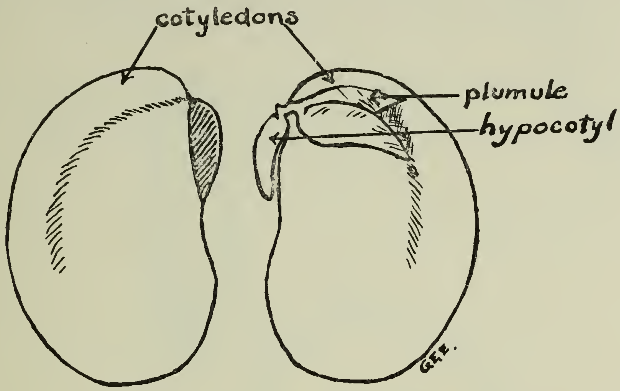

Fig. 5. Bean seed showing the cotyledons separated and exposing the embryo.

Fruit and Seed Distinguished.—The term seed is frequently and incorrectly applied to many of the small, dry, one-seeded, indehiscent fruits. The caryopsis or grain of wheat is known commercially as a seed as are the achenes of sunflower and rhubarb. A fruit is the matured ovary together with the seed or seeds. In the case of the one-seeded, indehiscent fruits, the seed is enclosed in the ovary wall, which has become hardened, whereas a many-seeded dehiscent fruit such as the pea, has the ovary wall or pericarp represented as the pod and the seeds are the enclosed "peas".

A ***caryopsis,*** (Fig. 6) such as the grain of wheat or of any other grass, is in reality a dry fruit containing one seed, and the fruit wall does not split open at maturity to allow the seed to escape. Further-

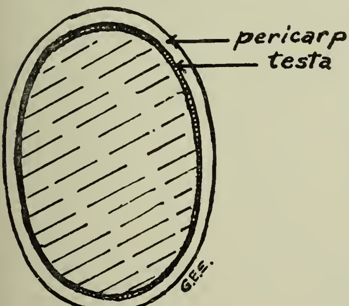

Fig. 6. Longitudinal section of a Caryopsis (Wheat) showing the pericarp and testa firmly grown together.

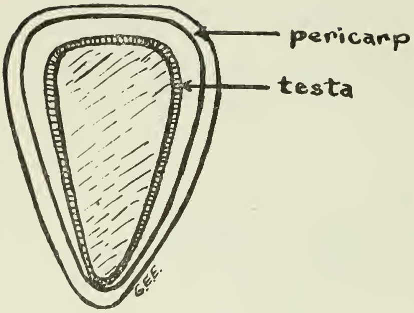
pericarp
testa
G.E.E.

Fig. 7. Longitudinal section of an achene (Sunflower) showing the seed free from the enclosing pericarp.

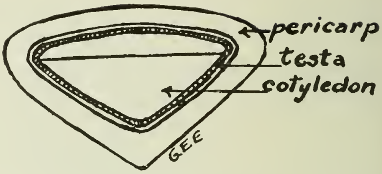
pericarp
testa
cotyledon
G.E.E.

Fig. 8. Cross-section of a nutlet (Motherwort) showing two flat sides (areas of cleavage where fruit split into nutlets) and relation of closely united pericarp and testa.

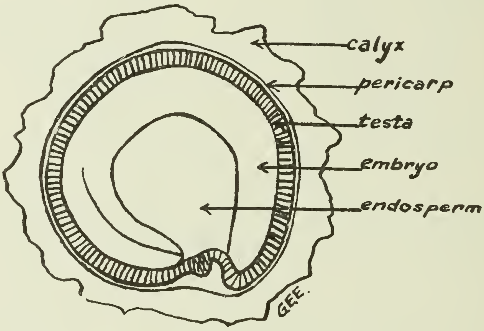
calyx
pericarp
testa
embryo
endosperm
G.E.E.

Fig. 9. Cross-section of an utricle (Beet) showing the loose, bladder-like calyx enclosing the pericarp which is not adherent to the testa.

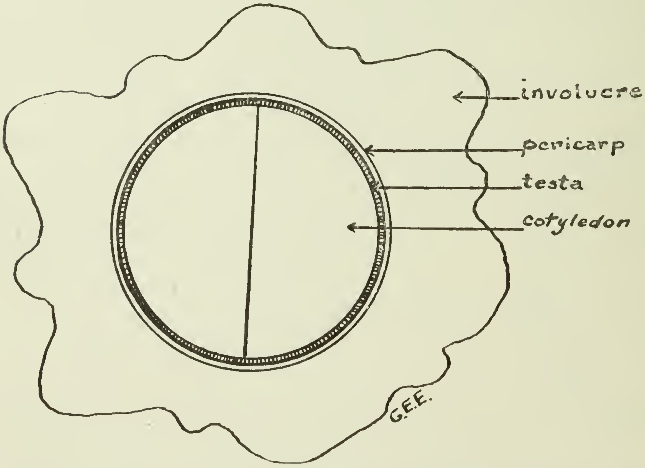
involucre
pericarp
testa
cotyledon
G.E.E.

Fig. 10. Cross-section of an involucre enclosing an achene (Kinghead) showing the relation of involucre to pericarp and testa.

more, the wall of the ovary is firmly grown to the seed-coats. An achene (Fig. 7) is a dry, non-splitting, one-seeded fruit resembling the caryopsis, but the ovary wall is not firmly grown to the seed-coats. A ***nutlet*** (Fig. 8) is a small, hard, usually one-seeded indehiscent fruit. An utricle (Fig. 9)) is a small, thin-walled, bladdery, one-seeded fruit. A true seed is shown in Fig. 11.

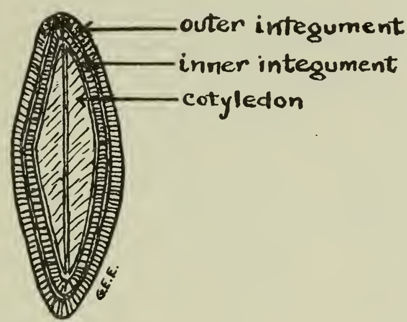

Fig. 11. Longitudinal section of a true seed (Pumpkin) showing outer and inner seed coats (integuments).

SEEDS GROUPED BOTANICALLY

The groupings as given below are based upon the "seeds" as they appear in commercial samples. The term "seed" used commercially may refer to either a true seed, botanically, or to a true seed plus other flower parts, such as ovary wall, involucre, calyx, etc. Thus a fruit, sometimes commercially known as a "seed", may occur as a caryopsis, achene, nutlet, utricle, and rarely as a druplet, berry, or follicle. Some genera may occur in more than one grouping, as for example, *Cenchrus and Chenopodium.*

Achene

Achillea
Ambrosia
Anthemis
Artemisia
Bidens
Carduus
Carex
Chenopodium
Chrysanthemum
Cichorium
Franseria
Geum
Grindelia
Helianthus
Iva
Laciniaria
Lactuca
Lygodesmia
Polygonum
Potentilla
Ranunculus
Ratibida
Rosa
Rumex
Sonchus
Taraxacum
Urtica

Caryopsis

Agropyron
Andropogon
Aristida
Avena
Bromus
Cenchrus
Echinochloa
Elymus
Eragrostis
Hordeum
Lolium
Panicularia
Panicum
Setaria
Sporobolus
Stipa
Syntherisma

Seed Surrounded by an Involucre

Ambrosia
Cenchrus
Franseria

Utricle

Amaranthus
Atriplex
Chenopodium
Cycloloma
Kochia
Salsola

Nutlet

Euphorbia
Galium
Gaura
Malva
Malvastrum
Lappula
Leonurus
Lithospermum
Lycopus
Nepeta
Prunella
Salvia
Teucrium
Verbena

True Seed

Abutilon
Agrostemma
Argemone
Asclepias
Brassica
Bursa
Camelina
Cerastium
Cleome
Conringia
Cuscuta
Geranium
Glycyrrhiza
Juncus
Lepidium
Linaria
Lychnis
Medicago
Melilotus
Oenothera
Opuntia
Oxalis
Plantago
Portulaca
Psoralea
Raphanus
Saponaria
Silene
Sisymbrium
Solanum
Stellaria
Thlaspi
Trifolium
Vaccaria
Verbascum
Vicia

Following are the noxious weed seeds of Colorado as enumerated in the Colorado Seed Act:

Common Name	**Botanical Name**	**Description on Page**
Large Crab-grass	Syntherisma sanguinale	26
Small Crab-grass	Syntherisma humifusum	26
Wild Oat	Avena fatua	28
Wild Barley	Hordeum jubatum	27
Chess	Bromus secalinus	30
Wild Buckwheat	Polygonum convolvulus	36
Corn Cockle	Agrostemma githago	44
Cow Cockle	Vaccaria vaccaria	43
Wild Mustard	Brassica arvensis	47
White Mustard	Brassica alba	47
Indian Mustard	Brassica juncea	48
Black Mustard	Brassica nigra	47
Low Hop Clover	Trifolium procumbens	54
Field Dodder	Cuscuta arvensis	61
Large-seeded Alfalfa Dodder	Cuscuta indecora	61
Small-seeded Alfalfa Dodder	Cuscuta planiflora	61
Black-seeded Plantain	Plantago rugelii	69
Buckhorn Plantain	Plantago lanceolata	69
Common Plantain	Plantago major	68
Pursh's Plantain	Plantago purshii	69
Poverty Weed	Franseria tomentosa	70
Poverty Weed	Iva axillaris	72
Canada Thistle	Carduus arvensis	76
Annual Sow Thistle	Sonchus oleraceus	80
Field Sow Thistle	Sonchus arvensis	81
Spiny Sow Thistle	Sonchus asper	80

I. GRASS FAMILY

Gramineae

The grass inflorescence or flowering group is made up of spikelets. A spikelet (Fig. 12), as the unit of inflorescence, consists of a stalk or axis (rachilla) bearing a number of two-ranked (distichous) bracts (glumes) the lowest two of which are empty. Above the two empty glumes, which subtend each spikelet, and attached to the rachilla, are one or more flowers. Each flower is borne in the axil of a bract called the lemma and subtended or enveloped by a two-keeled bract opposite the lemma, commonly referred to as the palet or palea. The back of the palet is toward the rachilla. The palet usually envelops the other parts of the flower with its infolded edges.

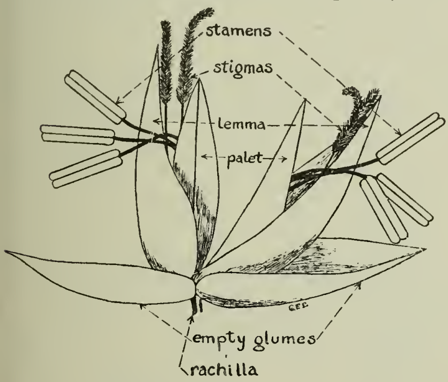

Fig. 12. Spikelet of Sandbur (Cenchrus tribuloides) showing rachilla, empty glumes palet, lemma, stamens and pistils. (After Vasey.)

The palet is never awned (bearded), the glumes and lemma are inserted on the rachilla, and the palet on a very short flower stalk (pedicel). The ovary of the grass flower contains a single ovule, which when fully developed or mature is a one-seeded grain-like fruit (caryopsis). The seed proper is enclosed by the pericarp (ovary wall) which is firmly attached to the seed coat (Fig. 6). There is usually an abundance of endosperm present. The germ (embryo) is located at the base of the grain on the side opposite the hilum (scar at the point of attachment of the grain to the stalk).

Considering the grains (fruits) of grasses collectively, there are two classes in which all grass grains may be placed: (1) Grains free at maturity, and (2) grains adherent to the palet and lemma at maturity.

KEY TO GENERA

- Seeds adherent (adnate) at maturity
  - Seeds enclosed by a persistent involucre armed with barb-like spines.......... 1..*Cenchrus*
  - Seeds not enclosed in a persistent involucre armed with barb-like spines
    - Seeds awnless
      - Margins of lemma inrolled along entire length...... 2..*Panicum*
      - Margins of lemma not inrolled along entire length
        - Margins of lemma inrolled except at the tip
          - Lemma shiny, smooth.......... 3..*Echinochloa*
          - Lemma distinctly roughened transversely........ 4..*Setaria*
        - Margins of lemma not inrolled.......... 5..*Syntherisma*
    - Seeds awned
      - Rachilla absent; lemma bearing three awns, two lateral ones united at the base—seeds scarcely wider than the awn .... 6..*Aristida*
      - Rachilla present
        - Rachilla prolonged behind palet as an awn........ 7..*Hordeum*
        - Rachilla not prolonged behind palet as an awn
          - Awn dorsal
            - Awn arising from a hyaline (transparent) lemma 8..*Andropogon*
            - Awn arising from an indurated (hardened) lemma .... 9..*Avena*
          - Awn not dorsal
            - Palet completely enclosed by the lemma; lemma indurated; a hard sharp point at base of seed ....10..*Stipa*
            - Palet not completely enclosed by the lemma
              - Lemma with a dorsal ridge (midrib)
                - Dorsally ridged throughout..........11..*Bromus*
                - Dorsally ridged at the tip only..........12..*Agropyron*
              - Lemma without a dorsal ridge (midrib)
                - Veins of lemma 3-7, distinct converging at apex ....13..*Lolium*
                - Veins of lemma obscure throughout........14..*Elymus*
- Seeds free at maturity
  - Seeds cylindrical, pointed at both ends
    - Seeds .4-.6 mm. long..........15..*Eragrostis*
    - Seeds .5-1.5 mm. long, often with a characteristic black mark at the base..........16..*Sporobolus*
  - Seeds not cylindrical; seeds shiny, turbinate in shape....17..*Panicularia*

1. Sandbur, Bur-grass

(*Cenchrus L.*)

Spikelet with an involucre of rigid, connate (united) spines or barb-like prickles; lemma and palet less hardened than in *Panicum*; lemma not inrolled at the margins, falcate (scythe-shaped); curved and flat, tapering gradually.

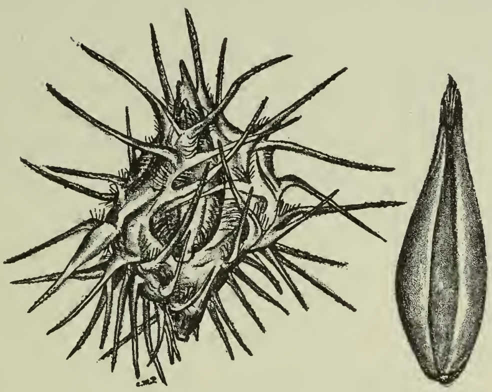

Fig. 13. Sandbur (Cenchrus tribuloides). Spiny involucre (left) x 5, caryopsis (right). x 9.

SANDBUR (*Cenchrus tribuloides L., Cenchrus carolinianus Walt.*) (Fig. 13).—Spikelets flattened, oval in shape, 4 to 5 mm. long, armed with stiff, stout prickles 2 to 5 mm. long.

2. Panic Grass, Witch Grass

(*Panicum L.*)

Lemma parchment-like, awnless, hardened, veins indistinct; margins of lemma inrolled; palet similar to lemma in texture, the margins firmly clasped by the inrolled lemma; seeds 1 mm.-3 mm. long rarely 4-5 mm., .5-1 mm. wide.

Key to Species

Seeds 1-1.5 mm. long, .8-1 mm. wide, oval in shape .... 1. .*P. capillare*

Seeds 2.5-2.8 mm. long, .8-1 mm. wide, tapering abruptly from the middle of the seed to the tip........................ 2. .*P. virgatum*

1. WITCH GRASS, OLD WITCH GRASS (*Panicum capillare L.*) (Fig. 14).—Seeds [1]light green-yellow to yellowish oil green, shiny, obscurely five-veined.

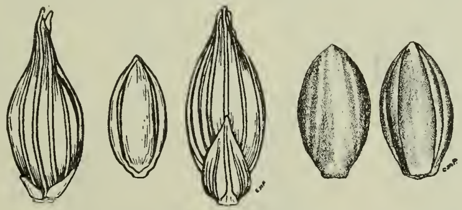

Fig. 14. Witchgrass (Panicum capillare). Fruits (left) enclosed in glumes, fruits (right) without glumes. x 9.

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[1] Seed colors were determined by comparing a number of seeds, of each species, with the colors in Ridgway's "Color Standards and Color Nomenclature".

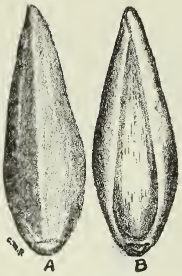

Fig. 15. Switch-grass (Panicum virgatum). A. Top view. B. Bottom view. x 12.

2. SWITCH GRASS, TALL SMOOTH PANICUM (*Panicum virgatum L.*) (Fig. 15).—Seeds coarsely mottled, sulphur yellow to smoke gray in color, shiny, obscurely five-veined at each end, the veins indistinct in the light colored band which crosses the center of the seed.

3. *Barnyard Grass, Jungle Rice*

(*Echinochloa Beauv.*)

Lemma parchment-like, accuminate (tapering at the end), awnless, margins enclosing the palet except at the apex; palet parchment-like, the tip or summit free from the inrolled lemma; seeds 3-3.5 mm. long, 1.5-2 mm. wide, tapering at the ends, shiny, smooth; rachilla absent.

BARNYARD GRASS (*Echinochloa crus-galli (L.) Beauv.*) (Fig. 16).—Seeds light orange yellow to buckhorn brown in color, shiny, obscurely three-veined.

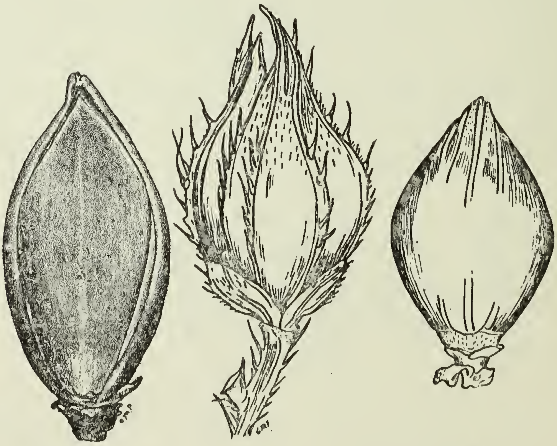

Fig. 16. Barnyard grass (Echinochloa crus-galli). Fruit (Center) enclosed in glumes, x 13 Fruit (right and left) without glumes. x 10.

4. *Foxtail Grass*

(*Setaria* Beauv., *Chaetochloa* Scribn.)

Lemma awnless, wrinkled, roughened transversely by fine branching ridges, dull, oval in shape, rarely smooth and shiny; palet rugose, both transversely and longitudinally, tip free from the inrolled lemma; rachilla absent; seeds 1.5-3 mm. long, 1-2 mm. wide, flat on one side, deeply rounded on the other, half circular (hemispheric) in cross section.

Key to Species

Seeds 2.5-3 mm. long, 1.5-2 mm. wide, 1-1.5 mm. thick, deeply wrinkled transversely .... 1..*S. glauca*

Seeds 1.5-2 mm. long, 1 mm. wide, .5-.8 mm. thick, wrinkles shallow; seeds dark brown and mottled, or spotted........ 2..*S. viridis*

1. YELLOW FOXTAIL (*Setaria glauca (L.) Beauv., Chaetochloa glauca (L.) Scribn*). (Fig. 17).—Seeds yellow ocher to mummy brown in color, deeply wrinkled, rounded side strongly arched.

2. GREEN FOXTAIL (*Setaria viridis (L.) Beauv., Chaetochloa viridis (L.) Scribn.*) (Fig. 18).—Seeds bone-brown to black in color, faintly wrinkled, mottled, faintly arched on the rounded side.

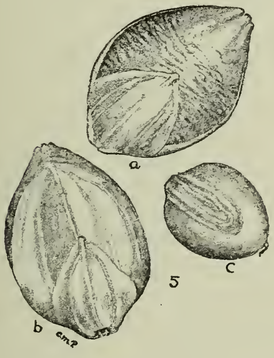

Fig. 17. Yellow Foxtail Setaria glauca). A. Bottom view. B. Top view. C. Caryopsis. x 9.

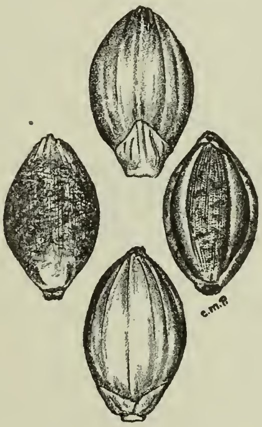

Fig. 18. Green Foxtail Setaria viridis). x 12. Fruits (top and bottom) enclosed in glumes, fruit (left) top view, fruit (right) bottom view.

5. *Crab-Grass*

(*Syntherisma Walt.*)

Lemma awnless, leathery, hardened, marked with fine longitudinal lines, margins not inrolled, transparent or nearly so; palet also leathery; seeds 1-3 mm. long, .5-1 mm. wide; rachilla absent.

Key to Species

Seeds 2.5-3 mm. long, 5-.8 mm. wide, slender, 4 to 5 times longer than wide .... 1..*S. sanguinale*

Seeds 1-1.5 mm. long, .5-.8 mm. wide, stout.................. 2..*S. humifusum*

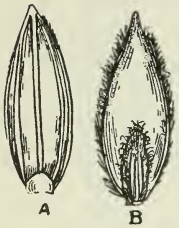

Fig. 19. Large Crab-grass (Syntherisma sanguinale). A. Top view. B. Bottom view. x 8.

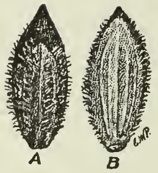

Fig. 20. Small Crab-grass (Syntherisma humifusum). A. Bottom view. B. Top view. x 16

1. LARGE CRAB-GRASS (*Syntherisma sanguinale* (*L.*) *Dulac.*) (Fig. 19).—Seeds dark ivy green to Andover green in color; twice as long as *S. humifusum.*

2. SMALL CRAB-GRASS (*Syntherisma humifusum* (*Pers.*) *Rydb.*) (Fig. 20).—Seeds black in color; almost as wide as long.

6. Triple-awned Grass
(*Aristida L.*)

The lemma tapers off into a terminal awn and two lateral awns as long or longer than the seed; palet thin, scale-like; rachilla not distinguishable; seed downy or smooth at the base, 7-16 mm. long, .5-1 mm. wide, scarcely wider than the awns.

WIRE GRASS (*Aristida longiseta Steud.*) (Fig. 21.—Awns neither twisted nor bent; spikelets purplish; awns 10-15 mm. long; lemma 5-12 mm. long.

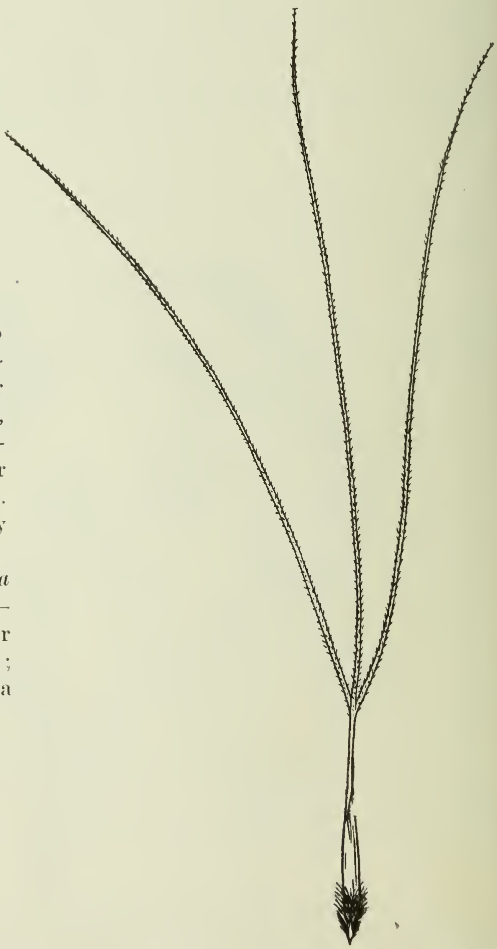

Fig. 21. Wire grass (Artistida longiseta). x 6.

7. *Barley, Squirrel-tail Grass*

(*Hordeum L.*)

The lemma, obscurely 5-veined, tapers off into a terminal awn from one to ten times the length of the seed; seeds usually in groups of three in the spikelet, the numerous awns, several long and some short, giving a brush-like appearance; palet slightly shorter than the lemma, with two distinct veins near the margin; rachilla prolonged behind the palet as an awn one-half to three-fourths as long as the seed; seeds 5-8 mm. long, 1-2 mm. wide.

Key to Species

Awns 8 to 10 times longer than seeds—central spikelet prominent 1..*H. jubatum*
Awns 1 to 2½ times longer than seeds—all spikelets of nearly the same size .... 2..*H. pusillum*

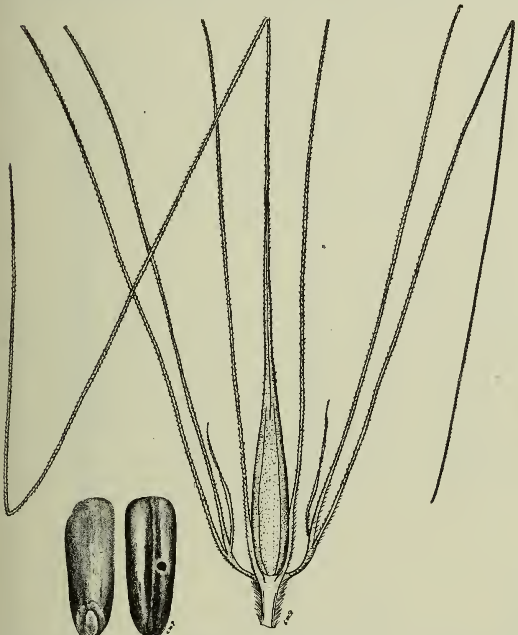

Fig. 22. Wild Barley (Hordeum jubatum). Caryopses (left). x 5. Spikelet (right). x 3.

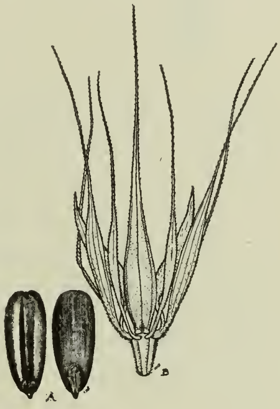

Fig. 23. Little Barley (Hordeum pusillum). A. Caryopses. x 10. B. Spikelet. x 4.

1. WILD BARLEY, SQUIRREL-TAIL GRASS (*Hordeum jubatum L.*) (Fig. 22).—Seeds buff to straw yellow in color; spikelets in clusters of three; only the central one fertile; central seed 5-7 mm. long, 1-1.5 mm. wide.

2. LITTLE BARLEY (*Hordeum pusillum Nutt.*) (Fig. 23).—Seeds pale, dull green yellow to straw yellow in color; spikelets in clusters of three; all fertile; seeds all the same size, 5-7 mm. long; .5-1 mm. wide.

8. *Beard Grass, Bluestem*

(*Andropogon* (Royen) L.)

Spikelets distinctly awned, the rachilla breaking off (articulating) below the glumes. The awn is dorsal (arising a noticeable distance below the apex of the hyaline (transparent) lemma but above its base). Awns 15-30 mm. long, as long or several times longer than the seed; palet and lemma are scale-like; rachilla prominent, half as long as the seed, distinctly hairy along its entire length or tipped with hairs; base of seed hairy at the point of articulation; seeds 2.5-8 mm. long, with a silky or downy appearance throughout.

Key to Species

Rachilla hairy near the tip, flattened ....1 *A. scoparius*
Rachilla hairy along its entire length, cylindrical ....2 *A. furcatus*

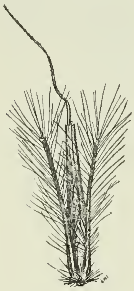

Fig. 24. Little Bluestem (Andropogon scoparius). x 3.

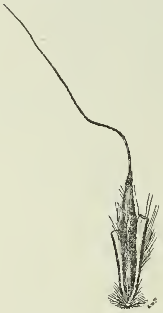

Fig. 25. Big Bluestem (Andropogon furcatus). x 2¼.

1. LITTLE BLUESTEM, BROOM BEARD GRASS (*Andropogon scoparius Michx.*) (Fig. 24).—Seeds chocolate to walnut brown in color, 5-7 mm. long, 1-1.5 mm. wide, slender; awn twisted and bent; seeds hairy at the base and near the tip of the rachilla.

2. BIG BLUESTEM, FORKED BEARD GRASS (*Andropogon furcatus L.*) (Fig. 25).—Seeds pyrite-yellow to chocolate color, 6-8 mm. long, 1.5-2 mm. wide, stout; awn straight, hair-like; seed and rachilla hairy throughout.

9. Oat Grass

(*Avena* (Tourn) L.)

Lemma 5-9 veined, hardened except toward the apex which is bidentate (having two teeth); lemma bearing a long dorsal awn (either straight or wanting in cultivated forms); palet papery, two-cleft at the apex, hairy at the base; rachilla cylindrical, slender, hairy, about one-fourth the length of the seed; seed 8-15 mm. long, 1-3 mm. wide, hairy at the base which usually appears as a perfect ring or sucker-like mouth with a tuft of hairs surrounding it; grain 2-7 mm. long, 1-2.5 mm. wide, hairy at the top and distinctly grooved.

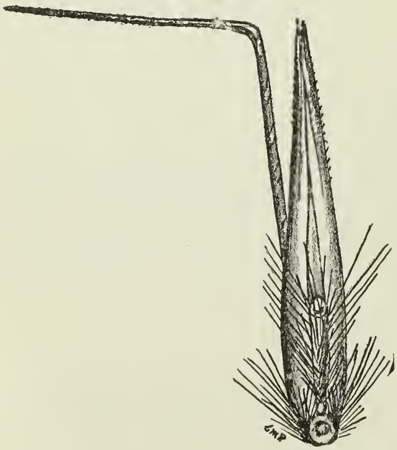

Fig. 26. Wild Oat Grass (Avena fatua). x 4.

1. WILD OAT GRASS (*Avena fatua L.*) (Fig. 26).—Seeds walnut-brown to straw-yellow in color, 10-15 mm. long 1.5-2.5 mm. wide; rachilla hairy; lemma with a sucker-like mouth at the base; dorsal awn, when present, stout, twisted, and bent.

10. Porcupine Grass, Spear Grass

(*Stipa L.*)

Lemma terminating in a single, stiff awn twisted one-half to three-quarters its length, straight near the tip, the straight portion bent at an angle of 60° to 90°; palet inclosed within the hardened lemma; rachilla reduced to a hard and sharp point at the base and armed with a tufted ring of short, stiff hairs directed upwards; seeds 8-20 mm. long, 1-1.5 mm. wide.

Key to Species

Seeds 18-20 mm. long, 1-1.5 mm. wide; awn prominently twisted	1..*S. spartea*
Seeds 10-12 mm. long, 1 mm. wide; awn twisted indistinctly..	2..*S. comata*

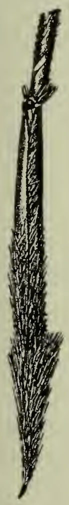

Fig. 27. Porcupine Grass (Stipa spartea). x 3.

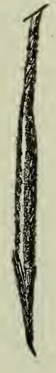

Fig. 28. Western Stipa (Stipa comata). X 2½.

1. PORCUPINE GRASS (*Stipa spartea Trin.*) (Fig. 27).—Seeds clay color, hairy at base; lemma somewhat shiny; awn bent one-half its length, 12-15 cm. long.

2. WESTERN STIPA (*Stipa comata Trin. & Rup.*) (Fig. 28).—Seeds straw-yellow in color, hairy at base; lemma dull; awn nearly straight, 10-12 cm. long.

11. Brome Grass

(*Bromus L.*)

Lemma convex or keeled, 5-9 veined or nerved, usually two-toothed at the apex, bearing a sub-terminal awn ranging from a mere blunt point to a slender, hair-like projection as long or longer than the seed; palet a little shorter than the lemma, two-keeled; rachilla cylindrical, very short, one-tenth to one-fifth the length of the seed, smooth or hairy; seed 6-12 mm. long, 1.5—4 mm. wide, many species widely flaring at the apex; grain flat, furrowed, dark reddish-brown in color, 5-8 mm. long.

Key to Species

Seeds plump, distinctly rounded on the back; lemma smooth or nearly so	1..*Bromus secalinus*
Seeds thin, flat to slightly round on the back; lemma very hairy throughout	2..*Bromus tectorum*

1. CHESS OR CHEAT (*Bromus secalinus L.*) (Fig. 29).—Seeds cinnamon-buff to clay color; lemma rounded on the back, obscurely 7-nerved, 6-8 mm. long, 1.5-2 mm. wide; awn from 4-6 mm. long, straight and stout; palet edges bear a single row of stiff hairs.

2. DOWNY BROME GRASS (*Bromus tectorum L.*) (Fig. 30).—Seeds wood-brown to buffy-brown in color, 8-10 mm. long, .5-1 mm. wide; awn 10-12 mm. long; lemma hairy with longer hairs at the margins.

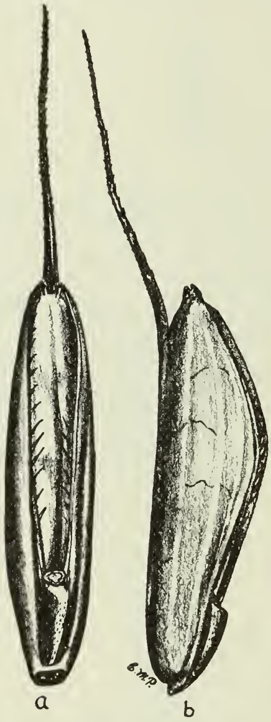

Fig. 29. Chess (Bromus secalinus) x 6. a. Bottom view. b. Side view.

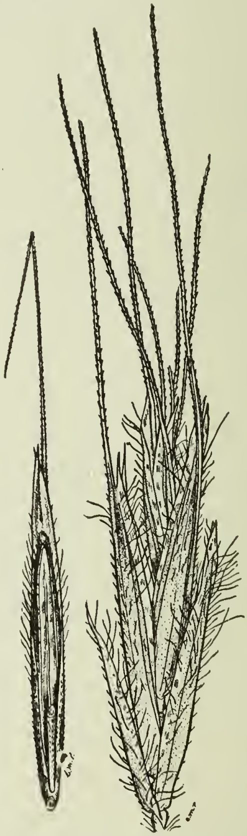

Fig. 30. Downy Brome Grass (Bromus tectorum). Floret (left), spikelet (right). x 5.

12. *Wheat Grass, Quitch Grass*

(*Agropyron Gaertner*)

Lemma convex or slightly keeled above, 5-7 veined, acute at the apex or bearing a sub-terminal awn either short and inconspicuous or rarely from one to three times the length of the seed; palet shorter than the lemma, bristly on the keel; rachilla smooth or hairy, cylindrical but narrower at the base; seed 8-12 mm. long, 1.5-2.5 mm. wide, slender, gradually tapering to a slender point or awn; grain oval to oval-round, hairy at the summit or tip.

Key to Species

Rachilla smooth .... 1..*A. repens*
Rachilla hairy .... 2..*A. tenerum*

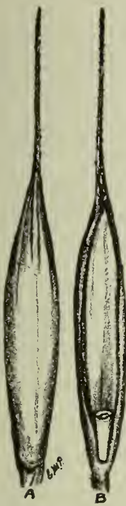

Fig. 31. Quack Grass (Agropyron repens). A. Top view. B. Bottom view. x 4.

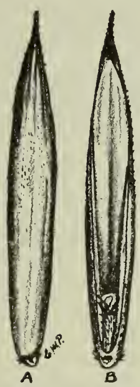

Fig. 32. Slender Wheat Grass (Agropyron tenerum). A. Top view. B. Bottom view. x 4.

1. QUACK GRASS (*Agropyron repens (L.) Beauv.*) (Fig. 31).—Seeds straw-yellow in color, 8-10 mm. long, 1.5-2 mm. wide; lemma smooth, strongly veined, bearing a sub-terminal awn from 2-4 mm. long; rachilla smooth; base smooth.

2. SLENDER WHEAT GRASS (*Agropyron tenerum Vasey*) (Fig. 32).—Seeds of same color, length, and width as *Agropyron repens;* lemma hairy at the base, elsewhere smooth, strongly veined bearing a sub-terminal awn 2-4 mm. long; rachilla hairy.

13. Darnel, Rye Grass

(*Lolium L.*)

Lemma 5-7 veined, veins converging at the two cleft apex; lemma bearing a sub-terminal awn one to one-half times as long as the seed; awn rough; palet shorter than the lemma; rachilla flattened, stout, cylindrical, usually smooth; seeds 5-7 mm. long, 1-2.5 mm. wide.

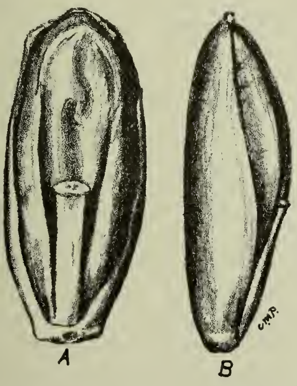

Fig. 33. Darnel (Lolium temulentum). A. Bottom view. B. Side view. x 9.

DARNEL (*Lolium temulentum L.*) (Fig. 33).—Seeds cinnamon in color, 4-5 mm. long, 2-2.5 mm. wide; lemma 7-veined, bifid at the apex and bearing a sub-terminal, rough awn one to one-half times the length of the seed; seeds stout, as thick as wide; rachilla stout, smooth.

14. *Wild Rye, Lyme Grass*

(*Elymus L.*)

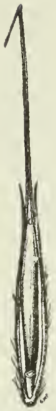

Fig. 34. Nodding Wild Rye (Elymus canadensis). x 3.

Lemma convex, faintly 5-veined, acute at the apex or bearing a sub-terminal, blunt, acute, or long awn; palet a trifle shorter than the lemma, velvety; rachilla one-fourth to one-sixth the length of the seed, cylindrical, distinctly narrower at the base, hairy or smooth, prominent; seed 7-15 mm. long, 1-2.5 mm. wide; grain flat or rounded on one side, grooved, hairy at the tip.

NODDING WILD RYE (*Elymus canadensis L.*) (Fig. 34).—Seeds pale green-yellow to straw-yellow in color, 10-12 mm. long, 1.5-2 mm. wide; lemma and rachilla hairy; awn 15-20 mm. long.

15. *Stink Grass, Skunk Grass*

(*Eragrostis Beauv.*)

Grains free at maturity, spherical to broad oval, or cylindrical in shape, pointed at the ends, smooth with a network of fine lines; translucent.

STINK GRASS (*Eragrostis megastachya* (*Koel.*) *Link.*) (Fig. 35).—Seeds maroon to claret-brown in color, spherical or cylindrical in shape, marked with a network of fine lines, translucent, pointed at the ends, .4-.6 mm. in diameter.

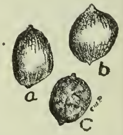

Fig. 35. Stink-grass (Eragrostis megastachya). x 10.

16. *Drop-seed, Rush Grass*

(*Sporobolus R. Br.*)

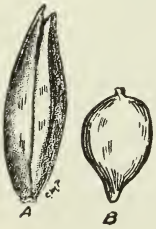

Fig. 36. Sand Drop-seed (Sporobolus cryptandrus). A. Floret. B. Caryopsis. x 30.

Grains free at maturity, pericarp, loosely enclosing the seed, often thin, and passing away early (evanescent); grains usually have a characteristic, crescent-shaped black mark at the base; many grains lose the pericarp early and the black mark is not in evidence; grains vary in color from Morocco-red to light buff, are usually translucent, flattened oval to disk shaped, .5-1.5 mm. long, .3-1 mm. wide.

SAND DROP-SEED (*Sporobolus crytandrus* (*Torr.*) *A. Gray*) (Fig. 36).—Seeds Morocco-red in color, .5 mm. long, .3-.4 mm. wide, black mark at the base minute and almost indistinct; seeds faintly translucent, oval in shape.

17. *Manna Grass, Meadow Grass*

(*Panicularia Fabr., Glyceria R. Br.*)

Grains free at maturity, flattened, napiform to obtusely wedge-shaped, distinctly pointed at one end, usually smooth, shiny, or dull shiny, sometimes marked with fine longitudinial lines; grains black to blackish-brown in color.

Key to Species

Seeds .5-.6 mm. long, .5 mm. wide, shiny black .... 1..*P. nervata*
Seeds 1.5-2.5 mm. long, .6-1 mm. wide, dull-shiny to oily...... 2..*P. grandis*

1. FOWL MEADOW GRASS (*Panicularia nervata (Willd.) Kuntze., Glyceria nervata (Willd.) Trin.*) (Fig. 37).—Seeds flattened, napiform, pointed at one end, shiny black, uniform in size and shape.

2. REED MEADOW GRASS (*Panicularia grandis (S. Wats.) Nash., Glyceria grandis Wats.*) (Fig. 38).—Seeds napiform to obtusely wedge-shaped, blackish-brown in color, variable in size and shape, more flattened than *P. nervata*.

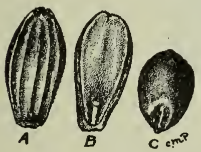

Fig. 37. Fowl Meadow-grass (Panicularia nervata). A. Top view. B. Bottom view. C. Caryopsis. x 18.

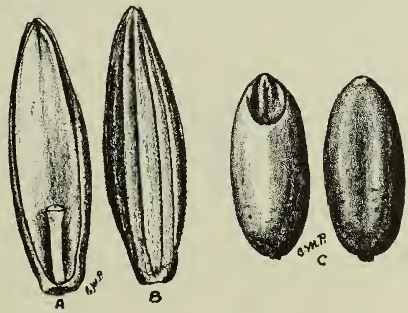

Fig. 38. Reed Meadow-grass (Panicularia grandis). A. Bottom view. B. Top view. C. Caryposes. x 10.

II. *SEDGE FAMILY*

(*Cyperaceae*)

In all sedges the 1-celled ovary bears a single, erect ovule. The matured ovary forms an achêne (a small, dry, hard fruit which does not split open at maturity). The fruit (seed) is flattened and either 3-angled or the shape of a double-convex lens (lenticular). The achene is completely surrounded by the perigynium (the inflated sac-like, beaked organ surrounding the ovary) rarely rupturing it in ripening.

Owing to the scarcity of herbarium material for comparison and the large number of species in this family, generic and specific characters have been omitted.

The accompanying illustration shows several species of sedge

(Carex) found in red top, blue grass, white clover, barley, and Sudan grass. (Fig. 39).

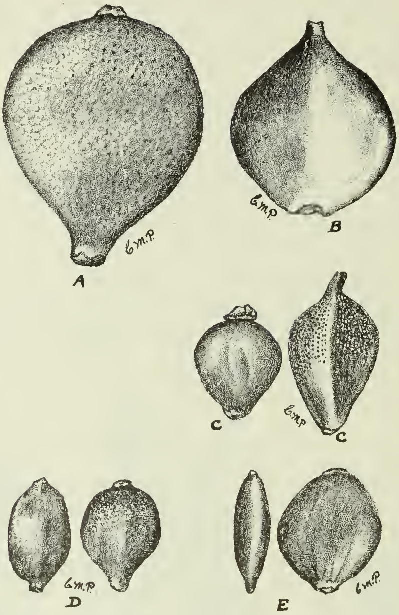

Fig. 39. Sedges (Carex spp.) A. In Barley. B. In Sudan Grass. C. In White Clover. D. In Red Top. E. In Bluegrass. x 15.

3. *RUSH FAMILY*

(*Juncaceae*)

Ovary a 1-3-celled capsule 3-valved; the minute embryo of the seed is enclosed by and at the base of the fleshy albumen; seeds three to many, often apiculate (with a minute point) or winged.

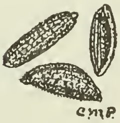

Fig. 40. Slender Rush (Juncus tenuis). x 35.

1. SLENDER RUSH (*Juncus tenuis Willd.*) (Fig. 40).—Seeds brick-red in color, apiculate, transversely netted with fine lines, translucent, winged at the tips or throughout the length of one side; seeds .2-.3 mm. long, often adhering to each other in groups of four or six.

4. *NETTLE FAMILY*

(*Urticaceae*)

Ovary 1-(rarely 2-)celled forming a 1-seeded fruit; fruit an achene; endosperm scant, oily or wanting; embryo straight.

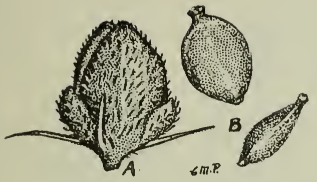

Fig. 41. Slender Nettle (Urtica gracilis). A. Calyx enclosing achene. B. Achenes. x 15.

SLENDER NETTLE (*Urtica gracilis Ait.*) (Fig. 41).—Seeds light wood-brown in color, dull, often roughened, ovate, compressed, summit terminating in a small knob-like projection; calyx somewhat persistent and armed at the base with several stinging hairs; seeds .8-1 mm. long, .5-.6 mm. wide.

5. *BUCKWHEAT FAMILY*

(*Polygonaceae*)

Ovary 1-celled, bearing a single, erect seed; fruit usually an achene; either double convex, compressed, 3-angled or rarely 4-angled, usually wholly or partly enclosed by the persistent calyx; seed shaped like the pericarp; endosperm mealy.

Key to Genera

Seeds margined or winged, usually enclosed by the calyx......	1..*Rumex*
Seeds not margined or winged, and seldom enclosed by the calyx	2..*Polygonum*

1. *Dock, Sorrel*

(*Rumex L.*)

Achenes 3-angled rarely 4-angled, with equal sides, distinctly winged or margined or with a persistent calyx; embryo curved or nearly straight, borne in one of the faces of the achene.

Key to Species

Seeds with distinct, flaring, calyx wings....................	1..*R. crispus*
Seeds without flaring calyx wings	
Seed edges obtuse or rounded............................	2..*R. acetosella*
Seeds edges acute or sharp..............................	3..*R. persicarioides*

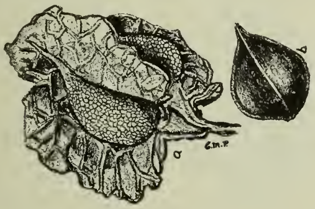

Fig. 42. Curled Dock (Rumex crispus). a. Calyx enclosing achene. x 9. b. Achene. x 6.

1. CURLED DOCK, YELLOW DOCK (*Rumex crispus L.*) (Fig. 42).—Seeds bay color, shiny, 2-2.5 mm. long, 1.5-2 mm. wide, 3-angled, sides equal, edges sharp or acute; sides slightly concave near the apex, which is abruptly acute.

2. SHEEP SORREL, FIELD SORREL (*Rumex acetosella L.*) (Fig. 43).—Seeds mahogany-red to bay color, shiny, persistent, roughened calyx usually present; achenes 1 mm. long, .8-1 mm. wide, 3-angled; sides equal, edges blunt or obtuse; sides slightly convex.

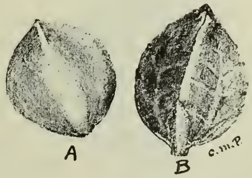

Fig. 43. Sheep Sorrel (Rumex acetosella). A. Achene. B. Calyx enclosing achene. x 16.

3. GOLDEN DOCK (*Rumex persicarioides L.*) (Fig. 44).—Seeds russet in color, shiny, 1 mm. long, .8-1 mm. wide, 3-angled, sides equal, ridges sharp or acute; achenes acutely pointed as in *R. crispus.*

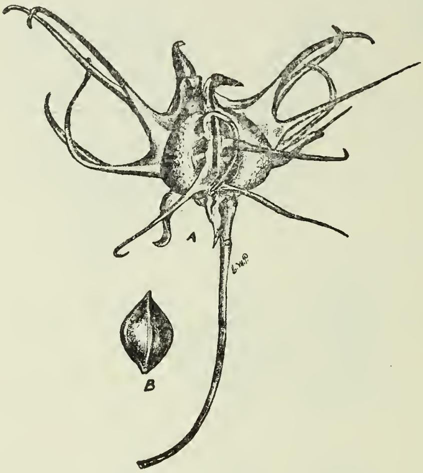

Fig. 44. Golden Dock (Rumex persicarioides). A. Calyx enclosing achene. B. Achene. x 10.

2. *Knotweed*

(*Polygonum* (*Tourn.*) *L.*)

Achenes either lenticular, compressed or 3-angled; sides usually unequal; achenes longer and usually larger than in *Rumex;* embryo near the end of the achene in one of its angles; achene usually exceeding the calyx in length when calyx is persistent.

Key to Species

Seeds 3-angled
  Seeds with equal sides.................................. 1..*P. convolvulus*
  Seeds with unequal sides................................ 2..*P. aviculare*
Seeds flat, napiform in shape
  Seeds nearly circular in outline, 3 mm. long, 3 mm. wide 3..*P. pennsylcanicum*
  Seeds oval in outline, 1.5-2 mm. long, 1-1.5 mm. wide.... 4..*P. persicaria*

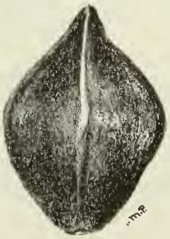

Fig. 45. Wild Buckwheat (Polygonum convolvulus). x 10.

1. WILD BUCKWHEAT (*Polygonum concolulus L.*) (Fig. 45).—Seeds dull black, the three sides equal and slightly concave, 2.5-3.5 mm. long, 2-2.5 mm. wide, 2-2.5 mm. thick; part of the calyx is often persistent; ridges rounded or obtuse.

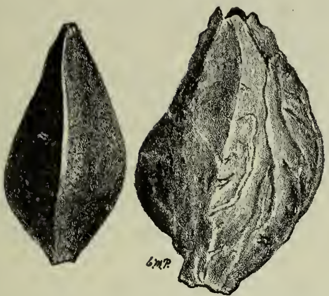

Fig. 46. Knotweed (Polygonum aviculare). Achene (left), calyx enclosing achene (right). x 12.

2. KNOTWEED (*Polygonum aviculare L.*) (Fig. 46).—Seeds maroon to black in color, the three sides unequal, gradually tapering to the acute apex; seeds 2-2.5 mm. long, 1.2-1.8 mm. wide, 1.2-1.8 mm. thick; part of the calyx is often persistent; ridges rounded or obtuse.

3. PENNSYLVANIA SMARTWEED (*Polygonum pennsylvanicum L.*) (Fig. 47).—Seeds shiny black, lenticular, 2.5-3 mm. long, 2.5-3 mm. wide, nearly circular in outline, apex a short, sharp point; part of the calyx often persistent.

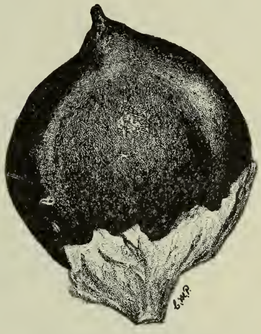

Fig. 47. Pennsylvania Smartweed (Polygonum pennsylvanicum). x 14.

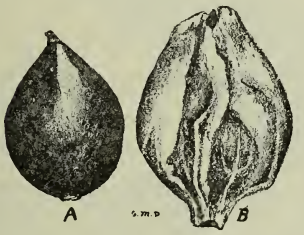

Fig. 48. Lady's Thumb (Polygonum persicaria). A. Achene. B. Calyx enclosing achene. x 11.

4. LADY'S THUMB (*Polygonum persicaria L.*) (Fig. 48).—Seeds shiny black, lenticular, 1.5-2 mm. long, 1-1.5 mm. wide, napiform, tapering to a point longer and not so abrupt as in *P. pennsylvanicum;* part of the calyx often persistent; 3-angled seeds resembling *R. crispus* but shiny black in color, often appear in this species.

6. GOOSEFOOT FAMILY
(*Chenopodiaceae*)

Ovary 1-celled, becoming a 1-seeded thin utricle (a small bladdery fruit) or rarely an achene; pericarp thin or coriaceous (leathery in texture); embryo coiled into a ring, entirely or partly around the mealy albumen (endosperm) when albumen is present, conduplicate (folded together lengthwise) or spirally coiled; calyx usually persistent, enclosing the fruit.

Key to Genera

Calyx in fruit surrounded by a wing (parallel to the flat surface)
Wing continuous, broad .... 1..*Cycloloma*
Wing 5-lobed, narrow .... 2..*Kochia*
Calyx not surrounded by a wing parallel to the flat surface
Calyx present
Embryo spirally coiled .... 3..*Salsola*
Embryo a ring .... 4..*Chenopodium*
Calyx absent; utricle enclosed in foliaceous (leaf-like) bracts 5..*Atriplex*

1. *Winged Pigweed*
(*Cycloloma Moq.*)

Utricle depressed, enclosed in the calyx; ovary 1-celled; seed flat, horizontal; calyx strongly keeled and appendaged with a broad, continuous, horizonal wing; endosperm mealy.

WINGED PIGWEED (*Cycloloma atriplicifolium* (*Spreng.*) *Coult.*) (Fig. 49).—Calyx 5-lobed, surrounded by a broad, horizontal, membranaceous wing; fruit flat, thin; with wing and calyx persistent seeds are 2.5-3 mm. across; with wing removed the seeds are 1-1.5 mm. across; wings white to neutral gray in color; calyx brown to black; seeds with calyx and wing removed, dull black in color.

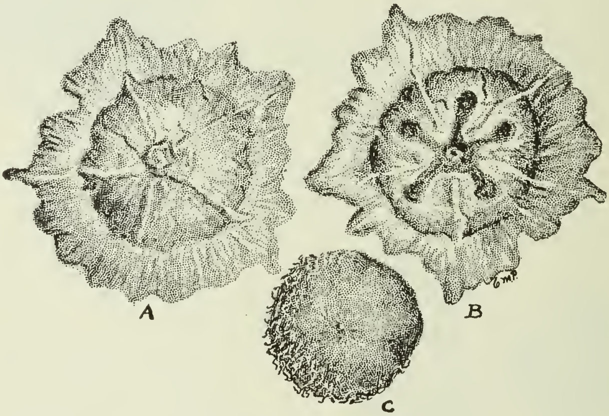

Fig. 49. Winged Pigweed (Cycloloma atriplicifolium). A. Top view. B. Bottom view. C. Utricle. x12.

2. *Burning Bush, Kochia*
(*Kochia Roth.*)

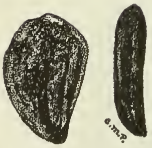

Fig. 50. Burning Bush (Kochia scoparia). Top view (left), edge view (right). x 11

Utricle ovate to pyriform in shape when calyx is removed; pericarp membraneous, not adherent to the seed; endosperm little or wanting.

BURNING BUSH (*Kochia scoparia* (*L.*) *Schrad.*) (Fig. 50).—Seeds with calyx persistent, pale smoke-gray in color, with calyx removed dull black; seed surface rough, wrinkled, irregularly and deeply concave on both sides; seed ovate to pyriform in shape, with little or no endosperm, 1-1.5 mm. long; .6-1 mm. wide.

3. *Saltwort, Russian Thistle*

(*Salsola L.*)

Calyx horizontally winged at the base of the fruit, the wings forming a broad scarious border; embryo coiled in a conical spiral; endosperm wanting.

RUSSIAN THISTLE (*Salsola pestifer A. Nels.*) (Fig. 51).—Seeds with calyx persistent, pale smoke-gray in color; with calyx and papery pericarp removed, the conical, spiral embryo is apricot-yellow in color; seeds including wing, 2.5-3 mm. wide, 1-1.5 mm. from base to summit; seeds with calyx removed 1-1.5 mm. wide, .5-1 mm. from base to summit.

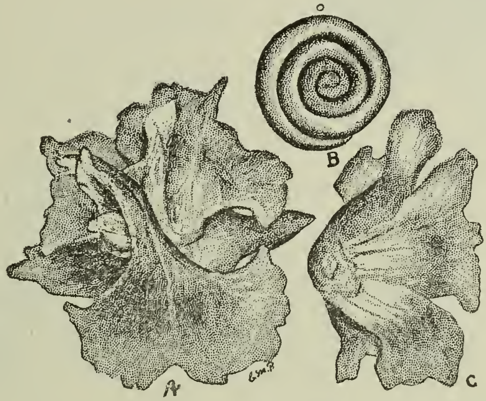

Fig. 51. Russian Thistle (Salsola pestifer). A. Calyx enclosing fruit. (top view). C. Calyx enclosing fruit. (side view). B. Embryo. x 12.

4. *Goosefoot*

(*Chenopodium (Tourn.) L.*)

Calyx 5- (rarely 4-) parted usually persistent; fruit lenticular, nearly circular in outline, the edge bluntly rounded; embryo annular (in the form of a ring), coiled partly or fully around the mealy endosperm.

LAMB'S QUARTER'S (*Chenopodium album L.*) (Fig. 52).—Seeds, with calyx persistent, pale smoke-gray to smoke-gray in color; with calyx and pericarp removed, seeds black and shiny; fruits 1-1.2 mm. wide, .5 mm. thick, edges rounded with a distinct groove leading from a marginal protuberance to the middle of each face; embryo annular, usually completely surrounding the endosperm.

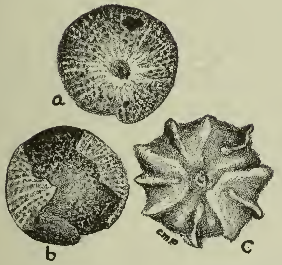

Fig. 52. Lamb's Quarters (Chenopodium album). a. Bottom view. b. Top view. c. Calyx enclosing utricle. x 12.

5. *Orache, Salt Bush, Shad-scale*

(*Atriplex (Tourn.) L.*)

Ovary 1-celled; utricle wholly or seldom partly enclosed in the foliaceous bracts which are often united at the top; calyx wanting; embryo coiled in a ring around the endosperm.

Key to Species

Bracts, enclosing the fruit, 2.5-3 5 mm. long.................. 1..*A. hastata*
Bracts, enclosing the fruit, 5-7 mm. long.................... 2..*A. semibaccata*

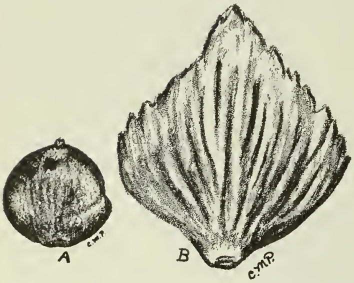

Fig. 53. Halberd-leaved Orache (Atriplex hastata). A. Utricle. B. Bracts enclosing utricle. x 10.

1. HALBERD-LEAVED ORACHE (*Atriplex hastata L.*) (Fig. 53).—Seeds, with enclosing bracts persistent, mahogany to black in color, rough, mealy; seeds with bracts removed, 1-1.5 mm. across, flat, thin, slate-black in color, with one protuberance, and a shallow groove which marks off the protuberance from the remainder of the seed.

2. AUSTRALIAN SALT BUSH (*Atriplex semibaccata*) (Fig. 54).—Seeds, with enclosing bracts persistent, pinkish-buff to cinnamon-buff in color, rough; seeds, with bracts removed, clay color; parts of the pericarp persist when the bracts are removed giving the seed a mealy, scurfy appearance; groove less distinct than in *A. hastata;* seeds, with bracts, 5-7 mm. long, 4-5 mm. wide in the widest part; seeds, without bracts or pericarp, 1.5 mm. across, flattened, thin.

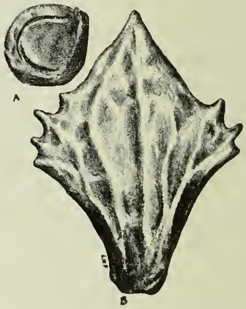

Fig. 54. Australian Salt Bush (Atriplex semibaccata). A. Utricle. B. Bracts enclosing utricle. x 5.

7. *AMARANTH FAMILY*

(*Amaranthaceae*)

Fruit a membranous 1-seeded utricle, ovoid or subglobose, circumscissile (dehiscing by a regular, transverse, circular line of division), bursting irregularly, or indehiscent; seeds mostly smooth and shiny; embryo annular; endosperm mealy, abundant.

Amaranth

(*Amaranthus* (*Tourn.*) *L.*)

Fruit an ovoid 1-seeded utricle, 2-3 beaked (ending in a prolonged tip) at the apex; calyx sometimes persistent; fruits opening transversely or sometimes bursting irregularly usually indehiscent; seeds smooth shiny, oval to circular in outline, lenticular; embryo coiled into a ring around the endosperm.

Key to Species

Seeds circular in outline or nearly so
  Seeds 1.2-1.5 mm. across each face......................... 1..*A. blitoides*
  Seeds .6-.7 mm. across each face............................ 2..*A. graecizans*
Seeds broadly ovate to oval in outline........................ 3..*A. retroflexus*

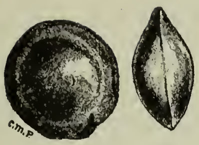

Fig. 55. Trailing Pigweed (Amaranthus blitoides). Top view (left), side view (right). x 10.

1. TRAILING OR PROSTRATE PIGWEED (*Amaranthus blitoides S. Wats.*) (Fig. 55).—Seeds shiny black, smooth, faintly marked with fine lines, flattened at the edge, distinctly margined, 1.2-1.5 mm. across each face.

2. TUMBLEWEED (*Amaranthus graecizans L.*) (Fig. 56).—Seeds shiny black, more shiny than *A. blitoides*, margin less distinct than preceeding, .6-.7 mm. across each face.

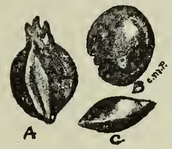

Fig. 56. Tumbleweed (Amaranthus graecizans). A. Calyx enclosing utricle. B. Top view. C. Edge view. x 10.

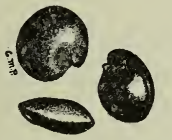

Fig. 57. Rough Pigweed (Amaranthus retroflexus). x 8.

3. ROUGH OR COMMON PIGWEED (*Amaranthus retroflexus L.*) (Fig. 57).—Seeds shiny black, as in *A. graecizans;* margins less pronounced than in *A. blitoides* or *A. graecizans*, 1-1.2 mm. long, .9-1 mm. wide.

8. PURSLANE FAMILY
(*Portulacaceae*)

Ovary 1-celled; capsule thin and translucent or hard and brittle, splitting open across, as a lid, or by 3-valves; seeds 2 to many, ovate to obscurely reniform in shape, globose or compressed; embryo curved around the mealy endosperm.

Purslane, Pussley
(*Portulaca (Tourn.) L.*)

Capsule 1-celled, thin and translucent, splitting or opening by a lid, many seeded; seeds flattened, ovate to reniform in shape.

COMMON PURSLANE (*Portulaca oleracea (Tourn.) L.*) (FIG. 58).—Seeds black, dull to dull-shiny, flattened, obscurely kidney shaped with a distinct white mark at the hilum; 3-4 concentric rows of minute projections give the seed a finely roughened appearance; the edges are faintly grooved by 2-3 annular lines; seeds .5-.8 mm. long.

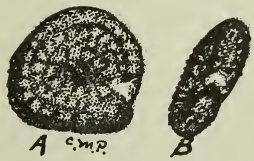

Fig. 58. Purslane (Portulaca oleracea). A. Top view. B. Edge view. x 22.

9. *CHICKWEED FAMILY*

(*Alsinaceae*)

Ovary 2-5 celled; fruit a capsule opening with from 2-10 valves; seeds several to many; embryo curved around the outside of the mealy endosperm.

Key to Genera

Seeds circular in outline—regular in shape	1..*Stellaria*
Seeds wedge-shaped—irregular in shape	2..*Cerastium*

1. Chickweed, Starwort

(*Alsine L., Stellaria L.*)

Ovary 1-celled; capsule short, opening by 5-6 valves; seeds flattened or globose.

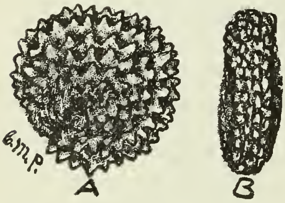

Fig. 59. Common Chickweed (Stellaria media). x 28.

1. COMMON CHICKWEED (*Stellaria media* (*L.*) *Cyrill.*, *Alsine media L.*) (Fig. 59).—Seeds deep-neutral-gray to dusky-purplish-gray in color; embryo so curved as to bring the apex and base nearly together; seeds circular in outline or nearly so, flattened, the sides marked with several rows of regular protuberances, arranged in concentric lines, which appear to end at the distinct notch in the edge; seeds are .6-.8 mm. across each face and .4-.5 mm. thick.

2. Mouse-ear Chickweed

(*Cerastium L.*)

Ovary 1-celled; capsule cylindrical, often curved, opening by 8-10 valves; seeds rough, irregular, marked with distinct protuberances or mere lines; markings may be very irregular or somewhat regular; seeds more or less flattened on sides and edges.

LARGE MOUSE-EAR CHICKWEED (*Cerastium vulgatum L.*) (Fig. 60).—Seeds brick-red in color; embryo so curved as to bring the apex and base nearly together; seeds usually wedge-shaped, flattened, notched at the narrow end, the sides marked with irregular, blister-like protuberances; seeds .4-.6 mm. long, .3-.4 mm. wide.

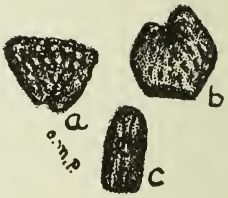

Fig. 60. Large Mouse-ear Chickweed (Cerastium vulgatum). a. & b. Top views, c. Edge view. x 20.

10. *PINK FAMILY*

(*Caryophyllaceae*)

Ovary 1-celled to incompletely 5-celled; capsule 1-5 celled, opening by 2-5 valves at the apex; seeds numerous, either with rounded or prickly projections, or rarely smooth; embryo usually coiled or curved around the mealy endosperm.

Key to Genera

Seeds spherical .... 1..*Vaccaria*
Seeds not spherical
  Seeds reniform in outline
    Seeds *very* flat, thin .... 2..*Saponaria*
    Seeds slightly flattened, thick
      Hilum with a distinct knob on two sides.................. 3..*Silene*
      Hilum nearly surrounded by a prominent protuberance.... 4..*Lychnis*
  Seeds heart-shaped in outline; seeds rough, dull black in color.. 5..*Agrostemma*

1. *Cow Herb, Cow Cockle*

(*Vaccaria Medic.*)

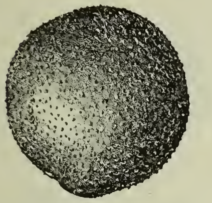

Fig. 61. Cow Cockle (Vaccaria vaccaria). X 10.

Ovary 1-celled; capsule opening by four tooth-like valves at the top; embryo curved.

COW COCKLE (*Vaccaria vaccaria* (*L.*) *Britton*) (Fig. 61).—Seeds dull black, smooth to slightly rough with microscopic, rounded points; seeds 2-2.5 mm. in diameter.

2. *Soapwort, Bouncing Bet*

(*Saponaria L.*)

Ovary 1-celled; capsule oval to oblong in outline, opening by four tooth-like valves at the top; embryo curved into a ring around the endosperm.

BOUNCING BET (*Saponaria officinalis L.*) (Fig. 62).—Seeds dull black, each face with 6-8 concentric rows of blister-like projections which appear to originate at the deep notch in the edge; each face is marked by a deep cup-like pit near the notch; seeds flat, reniform in outline, 1.2-2 mm. across each face.

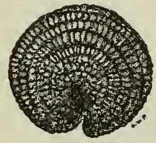

Fig. 62. Bouncing Bet (Saponaria officinalis). x 10.

3. *Catchfly, Campion*

(*Silenc L.*)

Ovary 1-celled; capsule opening by 6 or more valves at the top; seeds with rounded, prickly or spiny projections; seeds slightly flattened on each side, usually thick.

Key to Species

Seeds .5 mm. or less across each face......................... 1..*S. antirrhina*
Seeds .8-1 mm. across each face
  Projections on surface in regular concentric ridges.......... 2..*S. vulgaris*
  Projections on surface not in regular ridges.................. 3..*S. noctiflora*

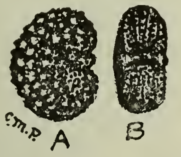

Fig. 63. Sleepy Catchfly (Silene antirrhina). A. Top view. B. Edge view. x 22

1. SLEEPY CATCHFLY (*Silcne antirrhina L.*) (Fig. 63).—Seeds slate black to black in color, with 4-5 irregularly concentric rows of blister-like projections on each face; seeds reniform to nearly circular in outline, slightly flattened, .4-.5 mm. across each face.

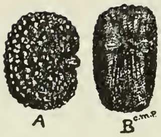

Fig. 64. Bladder Campion (Silene vulgaris). A. Top view. B. Edge view. x 10.

2. BLADDER CAMPION. (*Silene vulgaris* (*Moench.*) *Garcke*) (Fig. 64).—Seeds deep mouse-gray to mouse-gray in color, each face with 3-4 rows of regular, concentric rows of prominent, black tipped projections; seeds reniform to nearly circular in outline, flattened, .8-1 mm. across each face.

3. NIGHT-FLOWERING CATCHFLY (*Silene noctiflora L.*) (Fig. 65).—Seeds slightly lighter gray in color than *S. vulgaris*, each face with 7-10 irregular, concentric rows of black tipped projections, almost flat (not prominent); seeds reniform to nearly circular in outline, flattened, slightly larger than *S. vulgaris*, 1-1.2 mm. across each face.

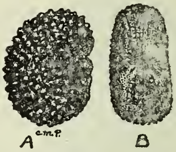

Fig. 65. Night-flowering Catchfly (Silene noctiflora). A. Top view. B. Edge view. x 10.

4. Campion, White Cockle

(*Lychnis* (*Tourn.*) *L.*)

Capsule opening by 8-10 valves at the top; other characters nearly identical with *Silene*.

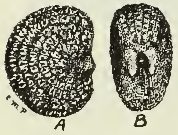

Fig. 66. White Cockle (Lychnis alba). A. Top view. B. Edge view. x 12.

WHITE COCKLE (*Lychnis alba Mill.*) (Fig. 66).—Seeds neutral-gray in color, projections and markings similar to *Silene noctiflora*, also similar in shape, but a trifle larger; as distinguished from *Silene noctiflora*, *Lychnis alba* has a prominent projection nearly surrounding the hilum, whereas the hilum of *Silene noctiflora* appears between two distinct knob-like projections; seeds 1-1.2 mm. across each face.

5. Corn Cockle

(*Agrostemma L.*)

Capsule 1-celled; seeds numerous, black, deeply grooved, curved so that the base and apex are brought nearly together.

CORN COCKLE (*Agrostemma githago L.*) (Fig. 67).—Seeds seal-brown to black in color, wedge-shaped to triangular, the top and bottom faces with 3-5 rows of regular, concentric, sharp projections, which become very small and indistinct near the hilum; the third face or edge opposite the hilum is very thick and ridged with 7-10 rings of sharp projections; seeds 2-4 mm. long, 2-2.5 mm. thick.

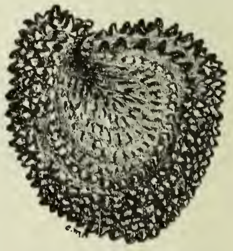

Fig. 67. Corn Cockle (Agrostemma githago). x 10.

11. CROWFOOT FAMILY
(*Ranunculaceae*)

Fruits either dry pods (follicles), achenes (seed like), or berries; seeds with a very small embryo, and hardened endosperm.

Crowfoot, Buttercup
(*Ranunculus* (*Tourn.*) *L.*)

Fruit an achene, usually flattened, and either smooth, or bearing minute, round tipped projections or prickles; fruit usually tipped with a short, curved, or straight point or *beak*.

Key to Species

Seeds swollen or inflated.. 1..*R. sceleratus*
Seeds compressed or flattened
  Beak of seed straight or nearly so.......................... 2..*R. acris*
  Beak of seed strongly hooked or curved..................... 3..*R. bulbosus*

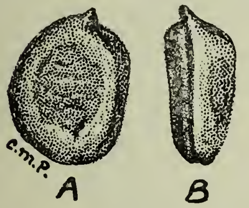

Fig. 68. Cursed Crowfoot (Ranunculus sceleratus). A. Top view. B. Edge view. x 34.

1. CURSED CROWFOOT, CELERY-LEAVED OR DITCH CROWFOOT (*Ranunculus scelaratus L.*) (Fig. 68).—Seeds honey-yellow in color, swollen or inflated, .5-.7 mm. long, marginless (without a distinct annular band around the edge of the seed), beak very short and straight.

2. TALL OR MEADOW BUTTERCUP (*Ranunculus acris L.*) (Fig. 69).—Seeds mahogany-red to Sudan-brown in color, about 3 mm. long, and 2 mm. wide, margins distinct, often lighter in color than the remainder of the seed; beak short, straight, or nearly so.

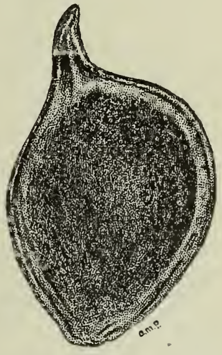

Fig. 69. Tall Buttercup (Ranunculus acris). x 12.

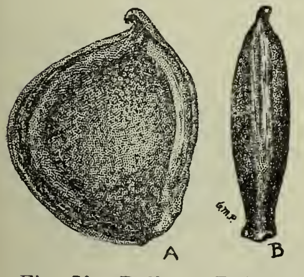

Fig. 70. Bulbous Buttercup (Ranunculus bulbosus). A. Top view. B. Edge view. x 10.

3. BULBOUS BUTTERCUP (*Ranunculus bulbosus L.*) (Fig. 70).—Seeds seal-brown in color, 2-3.5 mm. long, 1.5-2.5 mm. wide. margins very distinct, usually much lighter in color than the remainder of the seed; beak short (shorter than *R acris*) usually curved or strongly hooked.

12. *POPPY FAMILY*

(*Papaveraceae*)

Ovary 1-celled; fruit a capsule usually splitting open by a pore or by valves; seeds numerous, often crested (tufted); embryo very small and located at the base of the endosperm.

Prickly Poppy, Thistle Poppy

1. (*Argemone L.*)

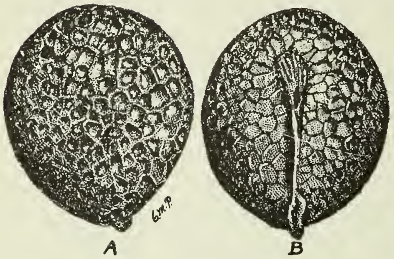

Fig. 71. White Prickly Poppy (*Argemone intermedia*). A. Top view. B. Bottom view. x 12.

Capsule oblong, prickly, opening at the top by 4-6 valves; seeds numerous, pitted and usually crested; endosperm oily.

WHITE PRICKLY POPPY (*Argemone intermedia Sweet*) (Fig. 71).—Seeds blackish-brown in color, oily, shiny, roughened owing to numerous shallow pits connected by a network of fine ridges; the wing-like ridge on one side is more prominent at the extremities; seeds nearly spherical, 1.5-2.5 mm. in diameter.

13. *MUSTARD FAMILY*

(*Brassicaceae Lind., Cruciferae B. Juss.*)

Ovary 2-celled, rarely 1-celled; fruit a capsule, usually splitting open at maturity; seeds generally so curved that the apex and base are brought nearly together; endosperm absent; embryo is usually large, filling the seed.

Key to Genera

- Seeds spherical except *Brassica alba*............................ 1..*Brassica*
- Seeds not spherical
  - Seeds flat (except *Lepidium campestre*)
    - Seeds with a single groove running nearly the length of the seed 2..*Lepidium*
    - Seeds with a number of circular grooves or concentric circles converging at the hilum......................... 3..*Thlaspi*
  - Seeds not flat
    - Seeds conical to cylindrical in shape, circular in cross-section
      - Seeds 1.5-2.5 mm. long
        - Seeds tawny color .... 4..*Camelina*
        - Seeds auburn color .... 5..*Conringia*
      - Seeds .6-1.3 mm. long.................................. 6..*Sisymbrium*
    - Seeds oblong
      - Seeds broadly oval to irregularly circular in cross-section.... 7..*Raphanus*
      - Seeds slightly oval in cross-section......................... 8..*Bursa*

1. *Mustard*

(*Brassica* (*Tourn.*) *L.*)

Pods either long, slender, or thick, nearly circular in outline or 4-sided; seeds mostly spherical, roughened or smooth; cotyledons of the seed folded together lengthwise.

Key to Species

Seeds smooth
  Seeds yellow .... 1..*B. alba*
  Seeds black .... 2..*B. arvensis*
Seeds not smooth
  [1]Seeds marked with pits deeper than the network of fine lines surrounding them.................................. 3..*B. nigra*
  [1]Seeds marked with pits no deeper than the network of fine lines surrounding them.................................. 4..*B. juncea*

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[1] Seeds of *B. nigra* can also be distinguished from *B. juncea* by their smaller size and redder color. Seeds of *B. juncea* are usually covered with a grayish bloom which can be easily rubbed off.

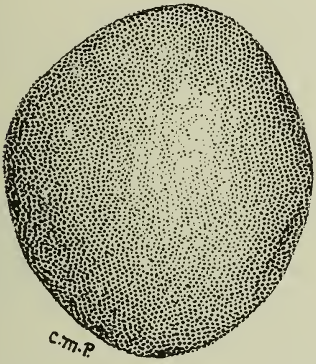


Fig. 72. White Mustard (Brassica alba). x 22.

1. WHITE MUSTARD (*Brassica alba* (*L.*) *Boiss.*) (Fig. 72).—Seeds dull, antimony-yellow in color, smooth, irregular in shape, mostly oblong to slightly flattened or nearly spherical, 2-2.5 mm. long.

2. WILD MUSTARD, CHARLOCK (*Brassica arvensis* (*L.*) *B. S. P.*) (Fig. 73).—Seeds dull, slate-black to black in color, smooth, spherical in shape, 1-1.8 mm. in diameter.

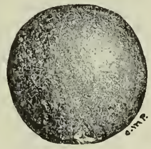


Fig. 73. Wild Mustard (Brassica arvensis). x 11.

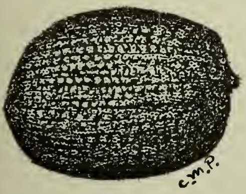


Fig. 74. Black Mustard (Brassica nigra). x 22.

3. BLACK MUSTARD (*Brassica nigra* (*L.*) *Koch.*) (Fig. 74).—Seeds brick-red in color, rough, spherical in shape, 1-1.5 mm. in diameter (usually noticeably smaller than either *B. arvensis* or *B. juncea*), surface marked with pits distinctly deeper than the network of fine lines bordering them.

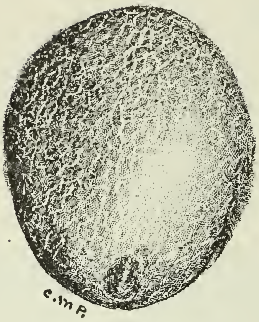


Fig. 75. Indian Mustard (Brassica juncea). x 22.

4. INDIAN MUSTARD (*Brassica juncea* (*L.*) *Cosson.*) (Fig. 75).—Seeds brick-red to wood-brown in color, usually covered with grayish bloom; seeds spherical in shape, 1.2-1.8 mm. in diameter, surface marked with a network of lines bordering pits, more shallow than in *B. nigra*, but each pit covering a greater area, giving the network a distinct and coarser appearance.

2. *Peppergrass, Bird-seed*

(*Lepidium L.*)

Pods either round or oblong, short; seeds mostly flat, grooved nearly their entire length.

Key to Species

Seeds flat .... 1. *L. apetalum*
Seeds conical or cylindrical .... 2. *L. campestre*

1. PEPPERGRASS, APETALOUS PEPPERGRASS (*Lepidium apetalum Willd.*) (Fig. 76).—Seeds dull cinnamon-rufous in color, each side marked with a distinct groove nearly the length of the seed; seeds often possess narrow, translucent, scale-like margins; seeds oval in shape, one extremity pointed, the other rounded, 1-1.7 mm. long, .6-.8 mm. across each face.

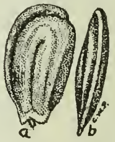


Fig. 76. Peppergrass (Lepidium apetalum). A. Top view. B. Edge view. x 15.

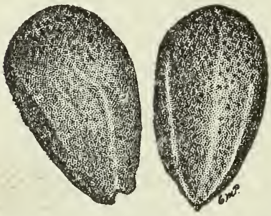


Fig. 77. Field Cress (Lepidium campestre). x 13.

2. FIELD CRESS, COW CRESS (*Lepidium campestre* (L.) R.Br.) (Fig. 77).—Seeds dull, bone-brown in color, conical to cylindrical in shape, circular in cross-section, surface roughened with two shallow grooves, meeting at the hilum and forming an angle of 60°; seeds rounded at one extremity, the other pointed, 1.7-2.5 mm. long, 1-1.5 mm. wide, in the widest part.

3. *Pennycress, Frenchweed, Wild Sweet Alyssum*

(*Thlaspi* (*Tourn.*) *L.*)

Pods either circular in outline, oblong or wedge-shaped; seeds 4-12 in each pod.

PENNYCRESS, FRENCHWEED (*Thlaspi arvense L.*) (Fig. 78).—Seeds dull black to oily black in color, each surface marked with 5-7 distinct concentric ridges converging at the hilum; seeds flat, ovate in shape, one extremity rounded, the other pointed, 1.6-2 mm. long, 1-1.5 mm. across each face at the widest part.

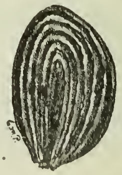


Fig. 78. Pennycress (Thlaspi arvense). x 12.

4. False Flax

(*Camelina Crantz.*)

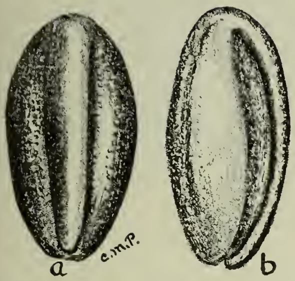


Fig. 79. False Flax (Camelina sativa). a. Top view. b. Side view. x 16.

Pods circular in cross-section, ranging from almost spherical to cylindrical in shape; seeds numerous, oblong, swollen or inflated.

FALSE FLAX (*Camelina sativa* (*L.*) *Crantz.*) (Fig. 79).—Seeds tawny to Sanford's-brown in color, irregularly oblong to cylindrical in shape, circular in cross-section; two distinct deep grooves (one on each side) constrict the seed nearly its length resulting in a rounded ridge, which often projects, lip-like, beyond the hilum; seeds 1.5-2.8 mm. long, .8-1.5 mm. wide, in the widest part.

5. Hare's-ear Mustard

(*Conringia* (*Heist.*) *Link.*)

Pod long and narrow, usually 4-angled; seeds oblong.

HARE'S-EAR MUSTARD (*Conringia orientalis* (*L.*) *Dum.*) (Fig. 80).—Seeds auburn color, usually oblong to cylindrical in shape, circular in cross-section, constricted by less distinct grooves but otherwise ridged as in *Camelina sativa*, the distinct lip-like projection usually extending beyond the hilum; surface of seed marked with shallow, minute pits; seeds 2-2.5 mm. long, 1.2-1.5 mm. wide in the widest part.

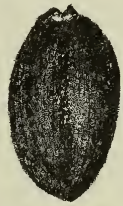


Fig. 80. Hare's-ear Mustard (Conringia orientalis). x 10.

6. Hedge Mustard, Tumbling Mustard

(*Sisymbrium* (*Tourn.*) *L.*, *Erysimum L.*, *Norta Adans.*)

Pods either awl-shaped or cylindrical, circular in cross-section, or 4-6 sided; seeds numerous, cylindrical, conical or irregular in shape.

Key to Species

Color raw-sienna to antique-brown.............................. 1..*S. altissimum*
Color bone-brown to hazel.. 2..*S. officinale*

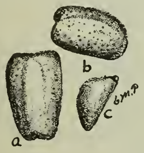


Fig. 81. Tumble Mustard (Sisymbrium altissimum). a. & b. Top view. c. Edge view. x 14.

1. TUMBLE OR TUMBLING MUSTARD (*Sisymbrium altissimum L.*, *Norta altissima* (*L.*) *Britton.*) (Fig. 81).—Seeds raw-sienna to antique-brown in color, nearly circular in cross-section usually with one groove nearly as long as the seed; seeds .7-1 mm. long, .4-.6 mm. wide.

2. HEDGE MUSTARD (*Sisymbrium officinale* (*L.*) *Scop.*, *Erysimum officinale L.*) (Fig. 82).—Seeds bone-brown to hazel in color, nearly circular in cross-section, grooved as in *S. altissimum* and more irregular in shape, .6-1.3 mm. long, .4-.6 mm. wide.

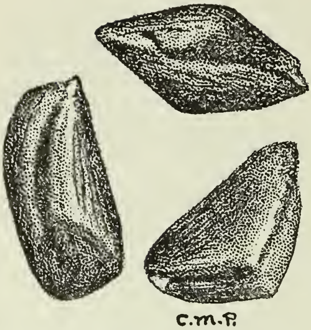


Fig. 82. Hedge Mustard (Sisymbrium officinale). x 33.

7. *Radish*

(*Raphanus L.*)

Pods oblong, circular in cross-section, tapering into a beak; pods rarely splitting open at maturity; seeds oblong to nearly spherical.

WILD RADISH, WHITE CHARLOCK (*Raphanus raphanistrum L.*) (Fig. 83).—Seeds vineaceous-brown to dark vineaceous-brown in color, surface marked with a network of fine lines and shallow pits; seeds 2-3 mm. long, 1.5-2 mm. wide, irregular in size and shape.

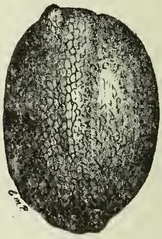


Fig. 83. Wild Radish (Raphanus raphanistrum). x 12.

8. *Shepherd's Purse*

(*Bursa Weber.*, *Capsella Medic.*)

Pods distinctly flattened, wedge-shaped or heart-shaped, notched at the top; seeds numerous.

SHEPHERD'S PURSE (*Bursa bursa-pastoris* (*L.*) *Britton.*, *Capsella bursa-pastoris* (*L.*) *Medic.*) (Fig. 84).—Seeds burnt-sienna in color, oblong, slightly oval in cross-section, each face marked with one distinct ridge separating the two distinct grooves, which are nearly as long as the seed and join at the end of the ridge, forming a loop around it; seeds .6-.8 mm. long, .3-.5 mm. wide.

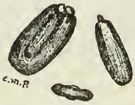


Fig. 84. Shepherd's Purse (Bursa bursa-pastoris). x 14.

14. *CAPER FAMILY*

(*Capparidaceae*)

Fruit a capsule or berry, elongated or flattened; seeds numerous, usually kidney-shaped, without endosperm; embryo coiled.

Bee Flower, Stink Flower

(*Cleome L.*, *Peritoma DC.*)

Capsule elongated, oblong; seeds numerous, appearing as though folded together lengthwise.

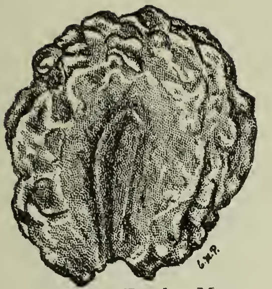


Fig. 85. Rocky Mountain Bee Plant (Cleome serrulata). x 10.

ROCKY MOUNTAIN BEE PLANT (*Cleome, serrulata Pursh., Peritoma serrulatum* (*Pursh.*) DC.) (Fig. 85).—Seeds dull, variable in color, mostly yellow-drab, bone-brown or black, flattened, grooved as though folded together lengthwise, roughened with blunt projections more distinct on the edges; seeds 3-4 mm. long, 2-2.5 mm. wide, usually ovate or oval-shaped, pointed at the hilum, rounded at the other extremity.

15. ROSE FAMILY

(*Rosaceae*)

Fruits variable, usually an achene or follicle, or a druplet; achenes may be hairy or smooth, and may split open or remain intact at maturity; seeds mostly without endosperm.

Key to Genera

Seeds many-sided—irregular in shape	1..*Rosa*
Seeds two-sided—regular in shape	
Seeds hairy	2..*Geum*
Seeds not hairy	3..*Potentilla*

1. Rose

(*Rosa* (*Tourn.*) *L.*)

Achenes numerous, enclosed in a berry-like, fleshy covering; achenes become hard and bony at maturity.

ARKANSAS ROSE (*Rosa arkansana, Porter*) (Fig. 86).—Seeds hazel to buckthorn-brown in color, prismatic though irregular in shape, with 3-6 faces, smooth, 3.5-4 mm. long, 2-3 mm. wide.

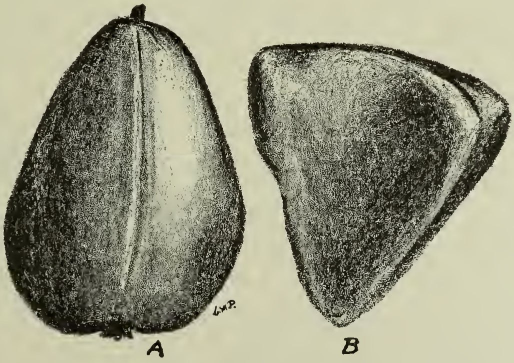


Fig. 86. Arkansas Rose (Rose arkansana) A. Two achenes united. B. Single achene, top view. x 10.

2. *Avens*
(*Geum L.*)

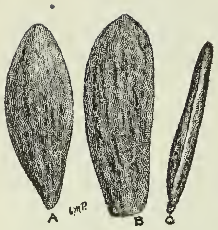


Fig. 87. Large-leaved Avens (Geum macrophyllum). A. & B. Top views. C. Edge view. x 6.

Achenes numerous, small, dry, usually hairy, with a characteristic tail or hooked beak.

LARGE-LEAVED AVENS (*Geum macrophyllum Willd.*) (Fig. 87).—Seeds Hay's russet to hazel in color, flattened, hairy, tipped with a long, slender, hooked beak (persistent style), usually as long as the achene; seeds 3-4 mm. long, .7-1 mm. wide.

3. *Cinquefoil, Five-finger*
(*Potentilla L.*)

The fruits are dry achenes; achenes usually swollen or inflated, kidney to oval-shaped, smooth or ridged.

ROUGH CINQUEFOIL (*Potentilla monspeliensis L.*) (Fig. 88).—Seeds buckthorn-brown in color, flat-oval in cross-section, kidney-shaped, marked with forked, rounded ridges, the longest ridge usually parallel to the rounded edge opposite the hilum, or point of attachment; seeds .5-.7 mm. long, .3-.5 mm. wide.

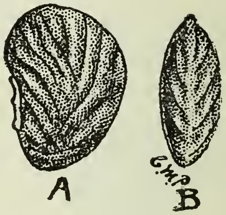


Fig 88. Rough Cinquefoil (Potentilla monspeliensis). A. Top view. B. Edge view. x 35.

16. *PEA FAMILY OR PULSE FAMILY*
(*Fabaceae Reichenb., Papilionaceae L. or Leguminosae Juss.*)

Fruit a more or less elongated pod splitting along its length by 2 valves or retaining its seeds at maturity; seeds usually without endosperm; the cotyledons (leaves of the embryo) are mostly thick and fleshy; seeds oval, spherical, cordate, cylindrical, reniform, and irregular; scar (hilum) and notch at the top, or side of the seed; hilum a line or point.

Key to Genera

Seeds spherical, or nearly so.................................... 1..*Vicia*
Seeds not spherical
  Seeds enclosed in a prickly, often persistent pod............. 2..*Glycyrrhiza*
  Seeds not enclosed in a prickly pod
    Seeds with the hilum near the middle of one side
      Seeds regular in shape
        Seeds 4-6 mm. long.................................... 3..*Psoralea*
        Seeds 1.5-2.5 mm. long................................ 4..*Trifolium* (*not T. procumbens*)
      Seeds usually irregular in shape, 1.5-3 mm. long, somewhat flattened .... 5..*Medicago*
    Seeds with the hilum near one end
      Seeds .7-1 mm. long, shiny.............................. 6..*Trifolium* (*T. procumbens*)
      Seeds 1.5-2.5 mm. long, dull............................ 7..*Melilotus*

1. *Vetch, Tare, Wild Pea*
(*Vicia L.*)

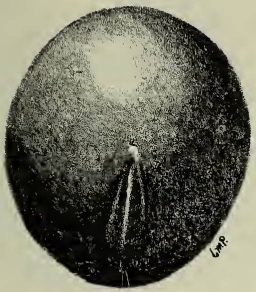


Fig. 89. Vetch (Vicia sp.) x 11.

Pods flat, 2-valved, splitting open at maturity; seeds few or many, irregular, spherical or globular in shape, usually smooth; hilum a line lighter in color than the rest of the seed; the seeds of most species are dull black.

VETCH (*Vicia sp.*) (Fig. 89).

2. *Liquorice*
(*Glycyrrhiza* (*Tourn.*) *L.*)

Pods oblong, compressed, covered with prickles or glands, seldom splitting open at maturity.

WILD LIQUORICE (*Glycyrrhiza lepidota* (*Tourn.*) *L.*) (Fig. 90).—Seeds mostly enclosed in a prickly pod; seeds black, irregular in shape, 2-3 mm. long, 1.8-2.2 mm. wide.

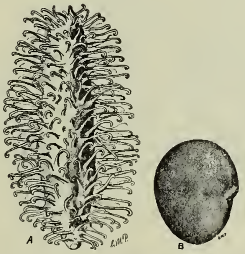


Fig. 90. Wild Liquorice (Glycyrrhiza lepiddota). A. Spiny pod x 2. B. Seed. x 6.

3. *Pomme de Prairie, Bread-root, Wild Alfalfa, Indian Turnip*
(*Psoralea L.*)

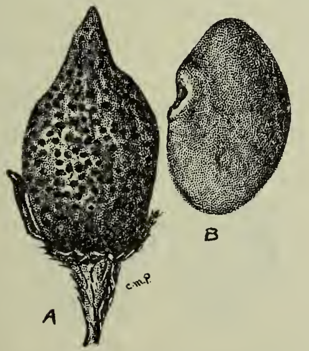


Fig. 91. Few-flowered Psoralea (Psoralea tenuiflora). A. Pod. B. Seed. x 5.

Pods seldom splitting open at maturity, covered with glandular dots, rough, each bearing a single seed; pods pointed, oval in outline.

FEW-FLOWERED PSORALEA, WILD ALFALFA, OR BREAD-ROOT (*Psoralea tenuiflora L.*) (Fig. 91).—Seeds buffy-brown to deep olive in color, rarely mottled, regular in shape; hilum in the middle of one edge, distinct, much lighter in color than the remainder of the seed; seeds 4-6 mm. long, 2.5-3 mm. wide.

5. *Medick, Lucerne*

(*Medicago* (*Tourn.*) *L.*)

Pods 1- to several seeded, coiled or curved, spiny, net-veined, or smooth, seldom splitting open at maturity; seeds regular or irregular in shape and size, generally kidney-shaped or broadly oval in outline, with a characteristic projection near the hilum.

BLACK MEDICK, NONESUCH (*Medicago lupulina L.*) (Fig. 92).—Pods black, marked with a distinct network of veins; seeds lime-green to clay color, somewhat flattened, broadly oval to kidney-shaped, with a distinct projection near the hilum, regular in shape, 1.5-2 mm. long, 1-1.3 mm. wide.

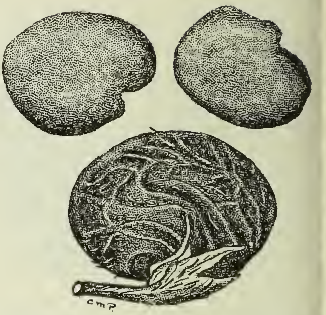


Fig. 92. Black Medick (Medicago lupulina). Seeds (top), pod (bottom) x 12.

6. *Clover, Trefoil*

(*Trifolium* (*Tourn.*) *L.*)

Pods oblong, circular in cross-section, splitting open by 1 suture, 1-6 seeded; seeds oval, broadly oval to nearly spherical, notched; hilum usually in the middle of one edge.

LOW HOP CLOVER (*Trifolium procumbens L.*) (Fig. 93).—Seeds shiny, cinnamon-buff to honey-yellow in color, notch and hilum near the top; seeds nearly cylindrical, .8-1 mm. long, .5-.7 mm. in diameter.

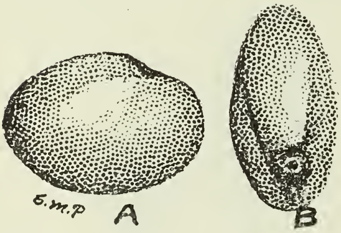


Fig. 93. Low Hop Clover (Trifolium procumbens). A. Top view. B. Edge view. x 22.

7. *Sweet Clover, Honey Clover*

(*Melilotus* (*Tourn.*) *Hill*)

Pods short and thick, straight, oval in outline, often nearly spherical, marked with a network of veins, seldom splitting open at maturity; seeds few, regular in shape, flattened, notched near the ends.

Key to Species

Surface of seeds rough.. 1..*M. indica*
Surface of seeds smooth
  Seeds grape-green in color.. 2..*M. officinalis*
  Seeds old-gold in color.. 3..*M. alba*

ANNUAL SWEET CLOVER (*Melilotus indica* (*L.*) *All.*) (Fig. 94).—Seeds dull, buffy-brown to deep olive in color, rough as though covered by minute grains, often with part of the pod persisting and giving the seed a scurfy appearance; seeds 1.2-1.7 mm. long, .8-1.5 mm. wide, broadly oval in outline, slightly flattened on two sides, notched at one end, regular in shape.

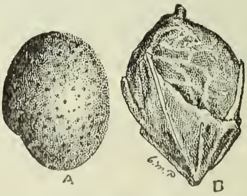


Fig. 94. Annual Sweet Clover (Melilotus indica). A. Seed. B. Pod. x 12.

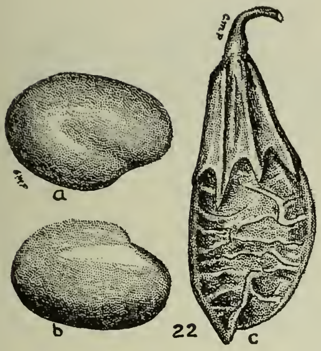


Fig. 95. Yellow Sweet Clover (Melilotus officinalis). a. & b. Seeds. c. Pod. x 11.

YELLOW SWEET CLOVER (*Melilotus officinalis* (*L.*) *Lam.*) (Fig. 95).—Seeds dull or occasionally shiny, grape-green in color, smooth, 1.5-2.3 mm. long, 1-1.5 mm. wide, oblong to long oval in outline, notched at one end, regular in shape.

WHITE SWEET CLOVER (*Melilotus alba Desv.*) (Fig. 96).—Seeds mostly dull, old-gold in color, smooth; other characters as in *M. officinalis*.

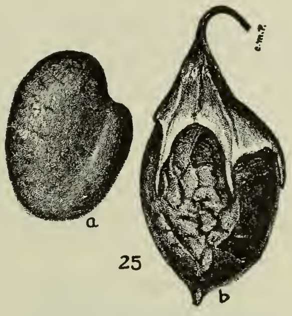


Fig. 96. White Sweet Clover (Melilotus alba). a. Seed. b. Pod. x 11.

17. GERANIUM FAMILY

(*Geraniaceae*)

A few species of *Geranium* seed are occasionally found in crimson clover and red clover. Seeds of these crops are imported from other states and the greater part of the crimson clover sold in the United States comes from Europe.

Of the many species of *Geranium* found in Colorado none of the seeds have appeared in our commercial samples of seed thus far. The scarcity of these seeds in crop seeds may be due largely to the method of seed dispersal. The sudden contraction of the coiled awn, resulting from contact with moisture, to which the awn is highly sensitive, ruptures the fruit and the seeds are shot out, sometimes traveling several feet.

Some of the Colorado species have been introduced from Europe, possibly in such importations as named above, others are thought to be native.

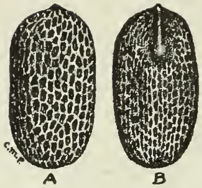


Fig. 97. Geranium (Geranium sp.) A. Top view. B. Bottom view. x 14.

GERANIUM (*Geranium sp.*) (Fig. 97).

18. WOOD SORREL FAMILY
(*Oxalidaceae*)

Fruit a capsule, nearly spherical or oblong, seldom berry-like; endosperm fleshy; embryo flat, straight.

Wood Sorrel, Yellow Wood Sorrel
(*Oxalis L., Xanthoxalis*, Small)

Capsule oblong or angular with flat sides, or cylindrical; seeds with the hilum and micropyle nearly together; seeds usually rough, ridged or grooved; endosperm abundant; embryo large and straight.

YELLOW WOOD SORREL (*Oxalis stricta L., Xanthoxalis stricta L.*) (Fig. 98).—Seeds bay to almost black in color, flat, egg-shaped to ovate in outline, rounded at one extremity, pointed at the other, roughened by 7-10 broken, white-tipped, transverse ridges and occasionally a groove running the length of the seed; the edges are usually marked by one white-tipped ridge extending almost entirely around the seed; seeds 1-1.2 mm. long, .6-.8 mm. wide.

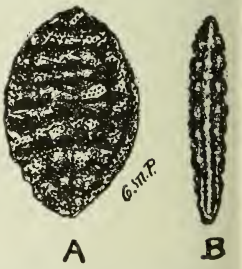


Fig. 98. Yellow Wood Sorrel (Oxalis stricta). A. Top view. B. Edge view. x 25.

19. SPURGE FAMILY
(*Euphorbiaceae*)

Fruit mostly a 3-lobed capsule, splitting into three parts (carpels) at maturity; seeds with the micropyle next the hilum, usually roughened by ridges or projections; endosperm oily and fleshy; embryo straight or slightly curved; cotyledons large.

Spurge, Carpet Weed
(*Euphorbia L., Lepadenia Raf.*)

Capsule smooth, three-lobed, with rounded or sharp angles; seeds occasionally with an appendage near the hilum; seeds angled, pitted, ridged or transversely wrinkled.

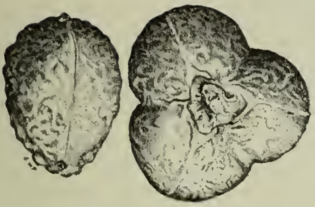


Fig. 99. Snow-on-the-Mountain (Euphorbia marginata). Fruit (right), nutlet (left). x 5.

SNOW-ON-THE-MOUNTAIN, WHITE-MARGINED SPURGE (*Euphorbia marginata Pursh., Lepadenia marginata (Pursh.) Niewl.*) (Fig. 99).—Seeds dull, castor-gray or white in color, 3.9-4.2 mm. long, 2.8-3 mm. wide, broadly oval in outline, circular in cross-section; surface netted, marked with rounded projections; a seam-like, dark ridge nearly as long as the seed is often distinct on one side.

20. *MALLOW FAMILY*

(*Malvaceae*)

Fruit usually a capsule, seldom a berry; seeds either kidney-shaped, circular in outline, nearly globular, or egg-shaped; endosperm little or abundant; embryo curved; cotyledons large.

Key to Genera

Seeds slightly flattened; cordate in shape .... 1..*Abutilon*
Seeds distinctly flattened
  Seeds reniform in shape, 1.3-2 mm. long........................ 2..*Malvastrum*
  Seeds nearly circular in outline, 1.2-1.5 mm. long .... 3..*Malva*

1. *Indian Mallow*

(*Abutilon (Tourn.) Mill.*)

Seeds numerous, more or less short, kidney-shaped; embryo curved; cotyledons large.

VELVET LEAF, INDIAN MALLOW (*Abutilon theophrasti Medic., Abutilon abutilon (L.) Rusby.*) (Fig. 100).—Seeds, dull, scurfy, mouse-gray in color, 3-3.5 mm. long, sides somewhat flattened, notched at one end, the ridge, from the longer projection formed by the notch, terminating in a lip-like shelf, which covers the base of the notch.

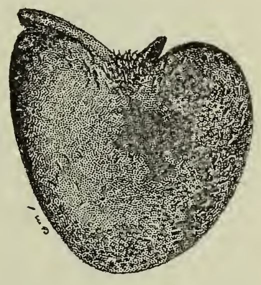


Fig. 100. Velvet Leaf (Abutilon theophrasti). x 10.

2. *Scarlet Mallow, False Mallow*

(*Malvastrum Gray., Sphaeralcea St. Hil.*)

Fruit circular in outline, flattened, splitting up into a number of nutlets at maturity; nutlets seldom splitting open; seeds short, kidney-shaped, flattened.

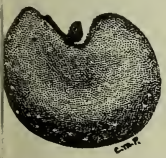


Fig. 101. False Mallow (Malvastrum coccineum). x 14.

FALSE MALLOW, RED FALSE MALLOW (*Malvastrum coccineum (Pursh.) Gray., Sphaeralcea coccinea (Nutt.) Rydb.*) (Fig. 101).—Nutlets cinnamon-buff in color; seeds olive-gray in color, flattened, often with a deep pit on each side, notched at the end, short kidney-shaped, 1.3-1.7 mm. long, 1-1.3 mm. wide, smooth; nutlets nearly circular in outline, the edge sharp on one side, sides wrinkled, flat.

3. Mallow
(*Malva* (*Tourn.*) *L.*)

Fruit as in *Malvastrum;* nutlets often splitting open at maturity; nutlets and seeds circualr in outline, flattened.

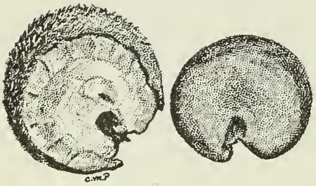


Fig. 102. Common Mallow (Malva rotundifolia). Nutlet (left), seed (right). x 15.

COMMON OR LOW MALLOW, CHEESES (*Malva rotundifolia L.*) (Fig. 102).—Nutlets and seeds of the same color as *Malvastrum coccineum;* seeds flattened, notched on one side, circular in outline, 1.2-1.5 mm. wide, smooth; nutlets smooth or very sighltly wrinkled, thin and seldom covering the entire seed.

21. CACTUS FAMILY
(*Cactaceae*)

Fruit a fleshy or sometimes dry berry; seeds usually hard and brittle in texture, smooth, with faceted surfaces; endosperm little or abundant.

Prickly Pear, Indian Fig, Cholla
(*Opuntia, Mill.*)

Berry often pear-shaped or nearly so, often spiny, fleshy or sometimes dry; seeds flattened, oval to nearly circular in outline; embryo curved around the endosperm.

PRICKLY PEAR, MANY-SPINED OPUNTIA (*Opuntia polyacantha Haw., Opuntia missouriensis DC.*) (Fig. 103).—Seeds white with a grayish area on each side, flattened, faceted, irregular with angles and depressions throughout and a distinct notch or slit at one side, as though the extremities had been pressed tightly together; a distinct bandlike margin, .6-1 mm. wide, completely encircles the seed; seeds 4-6 mm. across each face.

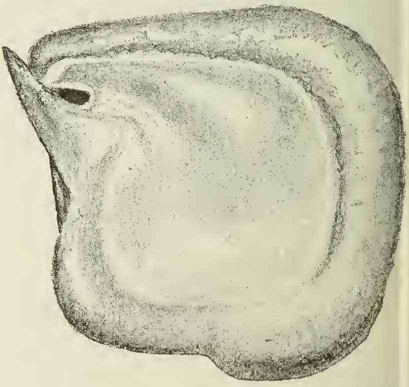


Fig. 103. Prickly Pear (Opuntia polyacantha) x 10.

22. EVENING PRIMROSE FAMILY
(*Onagraceae*)

Fruit a capsule or nut-like; seeds with the micropyle next th hilum; seeds small, mostly without endosperm.

Key to Genera

Seeds enclosed in a nutlet.. 1..*Gaura*
Seeds not enclosed in a nutlet; seeds prismatic, angled............ 2..*Oenother*

1. *Gaura, Butterfly Weed*

(*Gaura L.*)

Fruit hard and nut-like, angled or 3-4 ribbed, pointed or blunt, not splitting open at maturity; seeds 1-4 in a fruit.

Key to Species

Seeds pointed at tip, distinctly angled........................ 1..*G. coccinea*
Seeds blunt, faintly angled.................................... 2..*G. parviflora*

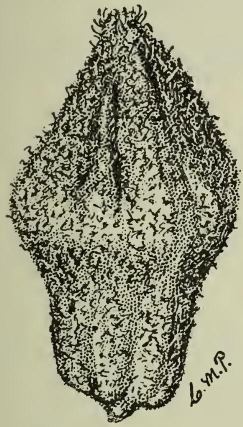


Fig. 104. Scarlet Butterfly-weed (Gaura coccinea). x 10.

1. SCARLET BUTTERFLY WEED OR GAURA (*Gaura coccinea Pursh.*) (Fig. 104).—Seeds pale grass-green in color, thick in the middle tapering towards each end, the base circular in cross-section, the top four-sided and terminating in a point; fruits 4.5-7 mm. long, 2-3 mm. wide in the widest part.

2. SMALL-FLOWERED BUTTERFLY WEED OR GAURA (*Gaura parviflora Dougl.*) (Fig. 105).—Seeds dark honey-yellow, spindle or ten-pin shaped, 8-veined, faintly angled at the large end, 6-8.5 mm. long, 1.7-2.5 mm. wide in the widest part.

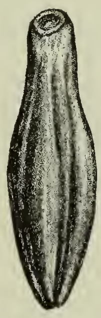


Fig. 105. Small-flowered Butter-fly-weed (Gaura parviflora). x 5.

2. *Evening Primrose*

(*Oenothera L.*)

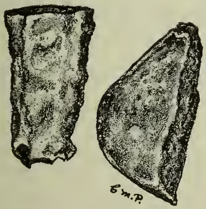


Fig. 106. Evening Primrose (Oenothera strigosa). x 11.

Fruit a capsule, 4-veined; seeds numerous, prismatic, angled.

EVENING PRIMROSE (*Oenothera strigosa Rydb.*) Seeds dull, russet in color, rough, angled, irregular, prism-shaped, 1.5-2.5 mm. long, .6-1.2 mm. wide in the widest part.

23. MILKWEED FAMILY

(*Asclepiadaceae*)

Fruit a follicle (a single carpel splitting along one suture) containing several or numerous seeds; seeds compressed, flattened, thin, with the hilum next the micropyle; endosperm thin, firm, and tough; cotyledons flat; embryo nearly as long as the seed.

Milkweed, Silkweed

(*Asclepias* (*Tourn.*) *L.*)

Follicles mostly thick, spindle-shaped, tapering at the end, either smooth or warty; seeds flat, margined, usually bearing a tuft of long silky hairs at the hilum; embryo large; endosperm thin.

Key to Species

Seeds 8-10 mm. long, margins without white spots .... 1..*A. speciosa*
Seeds 6-7 mm. long, margins with white spots .... 2..*A. galioides*

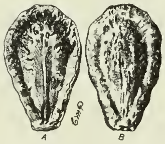


Fig. 107. Showy Milkweed (Asclepias speciosa). A. Top view. B. Bottom view. x 2.

1. SHOWY MILKWEED (*Asclepias speciosa Torr.*) (Fig. 107).—Seeds hazel in color, dull, 8-10 mm. long, 4-6 mm. wide, flat, thin, distinctly margined, ridged on one side nearly the length of the seed.

2. WHORLED MILKWEED (*Asclepias galioides L.*) (Fig. 108).—Seeds similar to *A. speciosa* in color, 6-7 mm. long, 3.5-4 mm. wide, otherwise as in *A. speciosa* except the margin which is marked with numerous white streaks and spots; the edge also is often white.

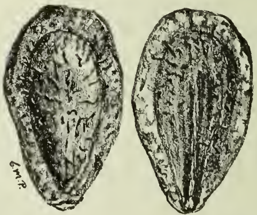


Fig. 108. Whorled Milkweed (Ascelepias galioides). Top view (left), bottom view (right). x 4.

24. DODDER FAMILY

(*Cuscutaceae*)

Capsule nearly globular or oval in outline, either bursting irregularly or not splitting open at maturity, 1-4 seeded; seeds smooth, or slightly rough, nearly globular or angular, with one or more flat surfaces; embryo curved or spiral, circular in cross-section; endosperm fleshy.

Dodder, Love-vine, Coral-vine

(*Cuscuta* (*Tourn.*) *L.*)

Capsule mostly 4-seeded; embryo spirally coiled in the fleshy endosperm; other characters as given in the family description.

Key to Species

Seeds with 2-3 flat faces
  Seeds .4-1.6 mm. in diameter .... 1..*C. planiflora*
  Seeds .9-1.2 mm. in diameter................................ 2..*C. arvensis*
Seeds usually without flat faces; seeds with a cup-like depression.. 3..*C. indecora*

1. SMALL-SEEDED ALFALFA DODDER, LESSER CLOVER DODDER (*Cuscuta planiflora Tenore., Cuscuta epithymum Murr.*) (Fig. 109).—Seeds light yellowish-olive to dark olive-buff in color, .5-.7 mm. long, .4-.6 mm. in diameter, rough, scurfy, usually with three flat faces, and one rounded face; of the three flat faces two are long, meeting through their length and forming a ridge, the other face is short and at the end of the seed, cutting the other two faces transversely; seeds either oblong, cylindrical or nearly spherical in shape.

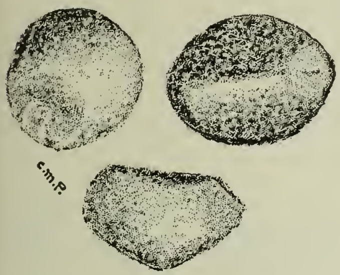


Fig. 109. Small-seeded Alfalfa Dodder (Cuscuta planiflora). x 36.

2. FIELD DODDER (*Cuscuta arvensis Beyrich*) (Fig. 110).—Seeds cinnamon-buff to light brownish-olive in color, .9-1.2 mm. in diameter, rough, usually with two to three flat faces and one rounded face as in *C. planiflora* though mostly unequal and not always meeting to form a ridge, often with only one flat face; seeds mostly spherical in shape.

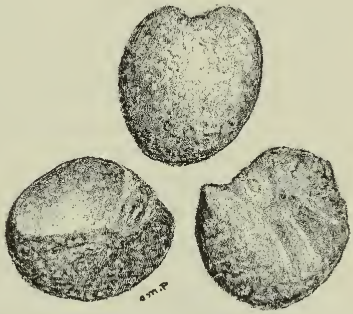


Fig. 110. Field Dodder (Cuscuta arvensis). x 20.

3. LARGE-SEEDED ALFALFA DODDER, PRETTY DODDER (*Cuscuta indeeora Choisy*) (Fig. 111).—Seeds of same color as *C. arvensis*, 1-1.7 mm. across each face, rough, usually with a deep or shallow cup-like depression on one side, seldom with even one flat face; seeds circular in outline, compressed.

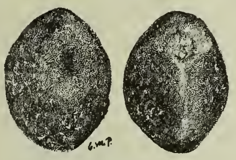


Fig. 111. Large-seeded Alfalfa Dodder (Cuscuta indecora). x 12.

25. BORAGE FAMILY
(*Boraginaceae*)

Fruit mostly of four 1-seeded nutlets, separating into two 2-seeded or four 1-seeded nutlets; endosperm often absent, but sometimes fleshy and abundant; embryo straight or curved; cotyledons flat or flat on one side and convex on the other.

Key to Genera

Seed armed with barbed prickles	1..*Lappula*
Seed smooth or wrinkled, unarmed	2..*Lithospermum*

1. Stickseed, Burseed

(*Lappula* (*Riv.*) *Moench*)

Fruit composed of 4 nutlets; nutlets armed with barbed prickles along the edge and sometimes with smaller ones on the rounded side (dorsal surface), the flat sides roughened with short hard processes.

Key to Species

Seeds with a cup-like depression	1..*L. cupulata*
Seeds without a cup-like depression	2..*L. occidentalis*

1. STICKSEED, HAIRY STICKSEED (*Lappula cupulata* (*A. Gray*) *Rydb.*, *Lappula texana* (*Scheele*) *Britton*) (Fig. 112).—Seeds buckthorn-brown in color, margin with 8-10 spines at regular intervals around the deep, cup-like depression; the rounded or dorsal side of the seed tapers to a point and is marked by short, rough projections, and a distinct ridge extending from the apex or center to a cleft in the spined margin; seeds nearly circular in outline, 1.5-2.2 mm. across the flat face, including the spines.

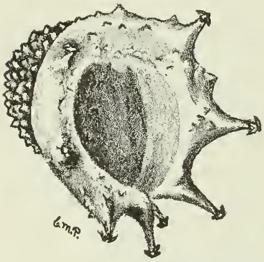


Fig. 112. Stickseed (Lappula cupulata). x 1-.

2. STICKWEED, STICKTIGHT (*Lappula occidentalis* (*S. Wats.*) *Greene*) (Fig. 113).—Seeds buckthorn-brown in color, margins with 10-15 stout spines lighter in color than the remainder of the nutlet; the rounded side of the seeds tapering to a point, is marked with distinct, rough projections and a ridge nearly as long as the rounded face, the other side is marked with a few, scattered, blunt projections; the spines either extend straight out from the margin or directly downward; seeds about 2 mm. long, 1 or 1.5 mm. wide, including the spines.

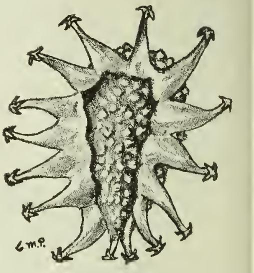


Fig. 113. Stickseed (Lappula occidentalis). x 12.

2. Gromwell, Puccoon, Indian Paint

(*Lithospermum* (*Tourn.*) *L.*)

Nutlets smooth, wrinkled or rough, hard or stony, often shiny and white, or nearly so.

NARROW-LEAVED PUCCOON (*Lithospermum linearifolium Goldie.*, *Lithospermum angustifolium Michx.*) (Fig. 114).—Seeds shiny, pale-olive-gray to white in color, ridged on one side, obscurely pitted, pointed at one end, truncate (as though cut off transversely) at the other; circular in cross-section; 2.5-4 mm. long, 2-2.5 mm. wide, in the widest part.

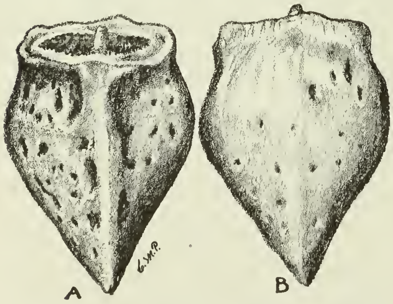


Fig. 114. Narrow-leaved Puccoon (Lithospermum linearifolium). A. Bottom view. B. Top view. x 12.

26. VERVAIN FAMILY

(*Verbenaceae*)

Fruit separating into 2 or 4 dry nutlets at maturity, or berry-like; endosperm little or absent, seldom fleshy; embryo straight.

Vervain, Verbena

(*Verbena* (*Tourn.*) *L.*)

Fruit separating into 4 dry nutlets at maturity; nutlets 1-seeded, either oblong, or long and narrow, hard, either smooth or rough.

Key to Species

Seeds faintly ridged on the rounded side........................ 1..*V. hastata*
Seeds strongly ridged on the rounded side
  Seeds 2-2.7 mm. long.. 2..*V. stricta*
  Seeds 1.5-2 mm. long.. 3..*V. bracteosa*

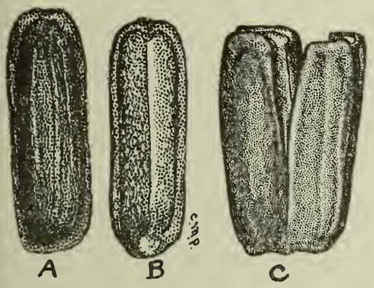


Fig. 115. Blue Vervain (Verbena hastata). A. Top view. B. Bottom view. C. Fruit splitting into nutlets. x 20.

1. BLUE VERVAIN (*Verbena hastata L.*) (Fig. 115).—Seeds Sanford's-brown in color, with two or three faint ridges on the back nearly as long as the seed, white-tipped at the base, the two flat sides meeting throughout their length and forming a distinct ridge; flat faces covered with numerous white, scurfy scales; seeds 1.2-1.7 mm. long, about .5 mm. wide.

2. HOARY VERVAIN (*Verbena stricta Vent.*) (Fig. 116).—Seeds bay color, with four or five distinct ridges on the back parallel to each other, extending over one-half the length of seed and then breaking up into a network of ridges which extend to the tip; the two flat faces meet as in *Verbena hastata* but are marked with a few, faint, white streaks; seeds 2-2.7 mm. long, .6-.7 mm. wide.

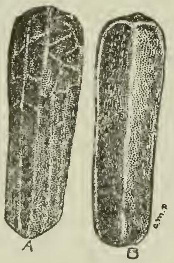


Fig. 116. Hoary Vervain (Verbena stricta). A. Top view. B. Bottom view. x 13.

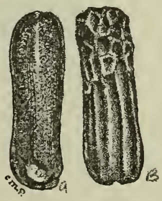


Fig. 117. Large-bracted Vervain (Verbena bracteosa). Bottom view (left), top view (right). x 14.

3. LARGE-BRACTED VERVAIN (*Verbena bracteosa Michx.*) (Fig. 117).—Seeds cinnamon-drab to drab in color, ridged as in *Verbena stricta*, white-tipped at the base; the two flat faces meet as in other species and are marked throughout with a mass of minute, roundish, drab-colored projections; seeds 1.5-2 mm. long, .4-.5 mm. wide.

27. *MINT FAMILY*

(*Labiatae B. Juss., Lamiaceae Lindl.*)

Fruit of 4 seed-like nutlets or achenes; nutlets 1-seeded, smooth or rough; endosperm usually absent or, if present, fleshy; embryo straight.

Key to Genera

- Seeds 3-angled, truncate
  - Seeds with a distinct band or margin around the edge............ 1..*Lycopus*
  - Seeds without a band or margin around the edge................ 2..*Leonurus*
- Seeds not 3-angled, not truncate
  - Seeds oval in outline
    - Seeds with 2 flat faces meeting in a ridge throughout their length
      - Seeds pointed at one end.................................. 3..*Prunella*
      - Seeds rounded at each end.................................. 4..*Salvia*
    - Seeds compressed, one end marked with two white dots........ 5..*Nepeta*
  - Seeds circular in outline, marked with a network of ridges........ 6..*Teucrium*

1. *Water Horehound, Bugle Weed*

(*Lycopus* (*Tourn.*) *L.*)

Nutlets with thickened margins, usually 3-angled, smooth, mostly truncate (ending abruptly as though cut off transversely) at the top, narrower at the base.

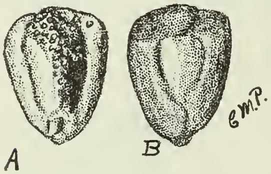


Fig. 118. Cut-leaved Water Horehound (Lycopus americanus). A. Bottom view. B. Top view. x 15.

CUT-LEAVED WATER HOREHOUND (*Lycopus americanus Muhl.*) (Fig. 118).—Seeds buckthorn-brown to mummy-brown in color, obscurely 3-angled, truncate, margins thick, wide, and usually distinct; seeds 1-1.5 mm. long, .6-1.3 mm. wide.

2. *Motherwort*

(*Leonurus L.*)

Nutlets 3-angled, smooth, truncate at the top, narrower at the base.

COMMON MOTHERWORT (*Leonurus cardiaca L.*) (Fig. 119).—Seeds buffy-brown to clove-brown in color, distinctly 3-angled and 3-sided, truncate, hairy at the top (truncate end), 1.3-1.8 mm. long, 1 mm. wide, in widest part.

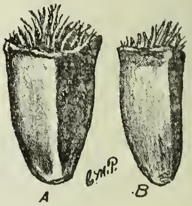


Fig. 119. Common Motherwort (Leonurus cardiaca). A. Bottom view. B. Top view. x 13.

3. *Self-heal, Heal-all*

(*Prunella L.*)

Nutlets oval in outline, smooth, rounded at the broad extremity, pointed at the other.

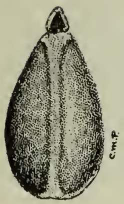


Fig. 120. Heal-all (Prunella vulgaris). x 15.

HEAL-ALL, CARPENTER-WEED (*Prunella vulgaris L.*) (Fig. 120).—Seeds chestnut-brown to hazel in color, oily, with one rounded face and two flat faces, nearly as long as the seed; a distinct band appearing as two parallel lines encircles the edge of the seed; a similar band runs the length of the seed on each side, dividing the seed into four equal areas; seeds 1.5-2 mm. long, 1 mm. wide, in the widest part, tapering to a white-tipped point.

4. Sage

(*Salvia* (*Tourn.*) *L.*)

Nutlets smooth, either oval or nearly spherical in outline, rarely cylindrical; mostly rounded at both ends, rarely pointed.

LANCE-LEAVED SAGE (*Salvia lanceolata Willd.*) (Fig. 121).—Seeds mottled, mostly pale orange-yellow in color, rounded at both ends, oval-shaped, with one rounded face and two flat faces meeting throughout their length and forming a ridge; seeds 1.7-2 mm. long, 1.2-1.5 mm. wide.

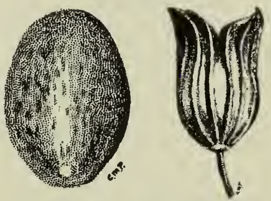


Fig. 121. Lance-leaved Sage (Salvia lanceolata). Calyx enclosing nutlets (right). x 3. Nutlet (left). x 13.

5. Catnip, Cat Mint

(*Nepeta L.*)

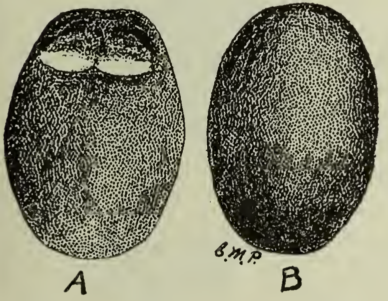


Fig. 122. Catnip (Nepeta cataria). A. Bottom view. B. Top view. x 25

Nutlets smooth, flattened or compressed, oval in outline.

CATNIP, CAT MINT (*Nepeta cataria L.*) (Fig. 122).—Seeds natal-brown to bone-brown in color, oval-shaped, rounded at both ends, one side rounded, the other compressed or flattened; marked with two small but distinct white spots at the base; seeds 1.2-1.5 mm. long, .7-1 mm. wide.

6. Germander, Wood Sage

(*Teucrium* (*Tourn.*) *L.*)

Nutlets circular in outline or broadly oval, usually wrinkled in the form of a network of ridges.

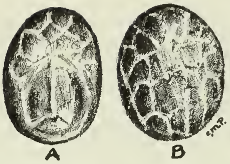


Fig. 123. Hairy Germander (Teucrium occidentale). A. Bottom view. B. Top view. x 11.

HAIRY GERMANDER (*Teucrium occidentale A. Gray*) (Fig. 123).—Seeds chestnut-brown to honey-yellow in color, circular in outline or nearly so, one side rounded, the other flat or concave and almost entirely occupied by a rounded scar; with the exception of the scar-like area, the seed is marked with a network of ridges.

28. *POTATO FAMILY, NIGHTSHADE FAMILY*

(*Solanaceae*)

Fruit a many-seeded berry or capsule; seeds numerous, flattened, with rounded projections, pitted or roughened, often hard and brittle, so curved as to bring the apex and base nearly together; endosperm abundant and fleshy; embryo curved or spirally coiled, circular in cross-section.

1. *Nightshade, Bittersweet, Horse Nettle*

(*Solanum* (*Tourn.*) *L.*)

Fruit a berry, mostly spherical in shape; seeds numerous, flattened.

Key to Species

Seeds smooth or nearly so	
Seeds 1.5-2.5 mm. long	1. *S. triflorum*
Seeds 1-1.5 mm. long	2. *S. nigrum*
Seeds pitted and rough	3. *S. rostratum*

1. THREE-FLOWERED OR CUT-LEAVED NIGHTSHADE (*Solanum triflorum Nutt.*) (Fig. 124).—Seeds buff-yellow to buckthorn-brown in color, flattened, oval in outline, 1.5-2.5 mm. long, 1.3-1.7 mm. wide; seeds appear faintly pitted when examined with a hand lens.

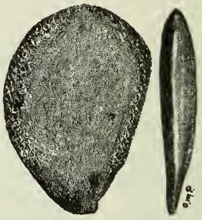


Fig. 124. Three-flowered Nightshade (Solanum triflorum). Top view (left), edge view (right). x 14.

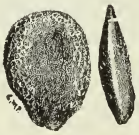


Fig. 125. Black Nightshade (Solanum nigrum). Top view (left), edge view (right). x 12.

2. BLACK OR COMMON NIGHTSHADE (*Solanum nigrum L.*) (Fig. 125).—Seeds black to clay color, flattened, oval or nearly circular in outline, 1-1.5 mm. long, .8-1 mm. wide; seeds appear pitted as in *Solanum triflorum.*

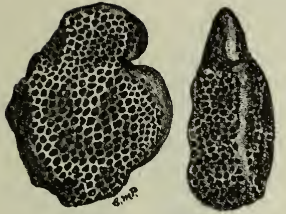


Fig. 126. Buffalo Bur (Solanum rostratum). Top view (left), edge view (right). x 10.

3. BUFFALO BUR, BEAKED NIGHTSHADE (*Solanum rostratum Duval.*) (FIG. 126).—Seeds dull black, flattened, irregular, mostly ovate in outline, surfaces deeply wrinkled and distinctly pitted; seeds 1.5-2.5 mm. across each face, .6-.8 mm. thick.

29. FIGWEED FAMILY

(*Scrophulariaceae*)

Fruit a capsule, rarely berry-like; seeds numerous, marked with a network of lines; ribbed transversely or with fine lines throughout the length of the seed or sometimes smooth; endosperm fleshy; embryo small, curved or straight.

Key to Genera

Seeds mostly circular in outline.................................. 1..*Linaria*
Seeds not circular in outline—angled........................... 2..*Verbascum*

1. Toadflax

(*Linaria* (*Tourn.*) *L.*)

Capsule thin, short, opening by 3 pores below and near the top; seeds numerous, wingless or winged, wrinkled or rough, mostly flattened but sometimes angled.

BUTTER-AND-EGGS, WILD SNAPDRAGON (*Linaria linaria* (*L.*) *Karst.*, *Linaria vulgaris Mill.*) (Fig. 127).—Seeds black, the wide notched wing buckthorn-brown to mummy-brown in color; seeds flattened, each face marked with numerous, minute rounded projections; wings marked with minute radiating lines nearly touching each other and almost parallel; seeds, including wing, 1.5-2 mm. across each face.

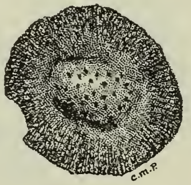


Fig. 127. Butter-and-eggs (Linaria linaria). x 14.

2. Mullein

(*Verbascum* (*Tourn.*) *L.*)

Capsule spherical or oblong in shape; seeds roughened, wingless.

GREAT MULLEIN, COMMON MULLEIN (*Verbascum thapsus L.*) (Fig. 128).—Seeds olive-brown in color, truncate and broader at one end and partially truncate or rounded at the other, marked with grooves as long as the seed and brokenly grooved, pitted or ridged transversely; seeds circular in cross-section, narrower at the tip, .5-.8 mm. long, .3-.5 mm. wide, in the widest part.

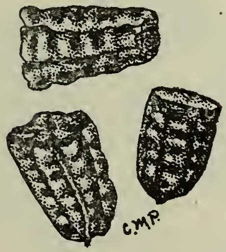


Fig. 128. Great Mullein (Verbascum thapsus). x 28.

30. PLANTAIN FAMILY

(*Plantaginaceae*)

Fruit a capsule splitting by a circular, horizontal line, the upper part coming off like a lid, or a nutlet not splitting open at maturity; seeds with flattened or concave faces; endosperm fleshy; embryo mostly straight.

Plantain, Rib-grass

(*Plantago* (*Tourn.*) *L.*)

Capsule thin and somewhat translucent; seeds numerous, with flattened faces, or hollowed out on one side giving a boat-like appearance.

Key to Species

Seeds with flattened faces
  Seeds black .... 1..*P. rugelii*
  Seeds brown in color .... 2..*P. major*
Seeds with a hollow or concave side
  Seeds with a transverse groove on the rounded side.......... 3..*P. purshii*
  Seeds not grooved on the rounded side...................... 4..*P. lanceolata*

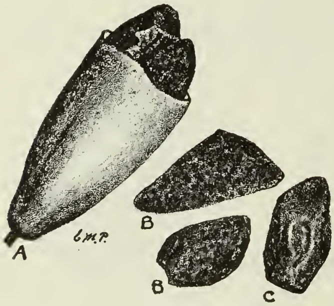


Fig. 129. Rugel's Plantain (Plantago rugelii). A. Capsule. B. Top view of seeds. C. Bottom view. x 10.

1. RUGEL'S PLANTAIN, RED-STEM PLANTAIN (*Plantago rugelii, Dec.*) (Fig. 129).—Seeds dull, mostly black, irregular, mostly oval in shape but often oblong or sometimes nearly square, rounded on one side, flattened into several faces on the other, the faces sloping away from a distinct scar near the center; seeds 1.2-2.5 mm. long, roughened but not marked with a network of ridges.

2. COMMON PLANTAIN, BROAD-LEAVED PLANTAIN (*Plantago major L.*) (Fig. 130).—Seeds dull, dark russet in color, irregular, varying in shape as in *P. rugelii*, marked, on the rounded side, with fine parallel lines running the length of the seed; the lines on the several faces appear to radiate from the central scar to the margin of the seed; seeds 1.2-2.5 mm. long.

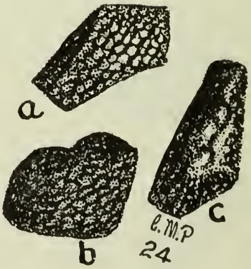


Fig. 130. Common Plantain (Plantago major). a. & b. Top view. c. Bottom view. x 13.

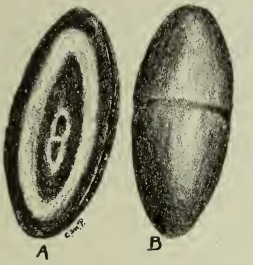


Fig. 131. Pursh's Plantain (Plantago purshii). A. Bottom view. B. Top view. x 15

3. PURSH'S PLANTAIN (*Plantago purshii R. & S.*) (Fig. 131).—Seeds dull, mostly russet in color, long oval in outline, rounded on one side and deeply concave on the other, the rounded side with a single transverse groove in the middle of the seed, the concave side with a lighter colored oval area, appearing as an oval within an oval, lighter in the middle and marked with two minute dark depressions (rarely one); seeds 1.5-2.5 mm. long, .7-1 mm. wide.

4. RIB-GRASS, BUCKTHORN OR SNAKE PLANTAIN (*Plantago lanceolata L.*) (Fig. 132).—Seeds shiny, mostly sudan-brown in color, rounded side smooth, the concave side with the margins inrolled and often nearly meeting so that the concave side may appear as a slit, only; the depressions at the bottom of the trough-like depression may be darker than the seed or of the same color; seeds 1.7-2.7 mm. long, .7-1 mm. wide.

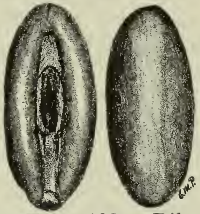


Fig. 132. Rib-grass (Plantago lanceolata). Bottom view (left), top view (right). x 15.

31. MADDER FAMILY

(*Rubiaceae*)

Fruit variable: A capsule, berry or stone fruit(drupe); seeds variable; seed-coats thin and more or less translucent or hard and brittle in texture.

Bedstraw, Cleavers

(*Galium L.*)

Fruit dry or fleshy, either bristly-hairy or with rounded projections or smooth; seeds spherical or nearly so, often rounded on one side and concave on the other; endosperm hard; embryo curved.

Key to Species

Seeds 2.5-3 mm. in diameter.. 1..*G. aparine*
Seeds 1-1.5 mm. in diameter.. 2..*G. boreale*

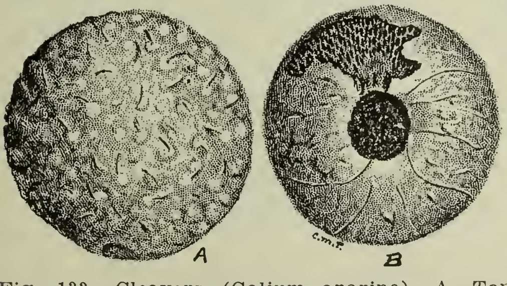


Fig. 133. Cleavers (Galium aparine). A. Top view. B. Bottom view. x 12.

1. CLEAVERS, GOOSE GRASS (*Galium aparine L.*) (Fig. 133).—Seeds neutral-gray to mouse-gray in color, spherical in shape, with a small pit-like depression or scar on the surface; seeds rough, covered with short, hooked bristles; fruits 2.5-3 mm. in diameter.

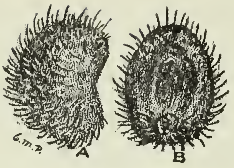


Fig. 134. Northern Bedstraw (Galium boreale). A. Side view B. Bottom view. x 12.

2. NORTHERN BEDSTRAW (*Galium boreale L.*) (Fig. 134).—Seeds cinnamon-brown to mummy-brown in color, broadly to nearly spherical in shape, deeply concave on one side, rounded on the other, rough, covered with bristly hairs; seeds 1-1.5 mm. long, or across each face when circular in outline.

32. RAGWEED FAMILY

(*Ambrosiaceae*)

Fruits (achenes) at maturity enclosed in either a beaked, bur-like or spiny involucre, or achenes winged or not winged; with pappus (growth or crown formation at the summit of the achene), occurring as hairs, scales or bristles.

Key to Genera

Seeds enclosed in an involucre at maturity
  Seeds armed with short, slender spines throughout.............. 1..*Franseria*
  Seeds armed with stout projections at the summit................ 2..*Ambrosia*
Seeds not enclosed in an incolucre at maturity; seeds compressed,
    without hairs or pappus.. 3..*Iva*

1. Poverty Weed, Bur Ragweed

(*Franseria, Cav.*)

Fruit (achene) enclosed in a spiny, beaked involucre which becomes bur-like at maturity; involucres oval or nearly spherical, rarely splitting open at maturity.

POVERTY WEED (*Franseria tomentosa A. Gray*) (Fig. 135).—Seeds light wood-brown to russet in color, armed with short, slender spines throughout; including spines, the seeds are 4-6 mm. long, 3.5-6 mm. wide, circular in cross-section.

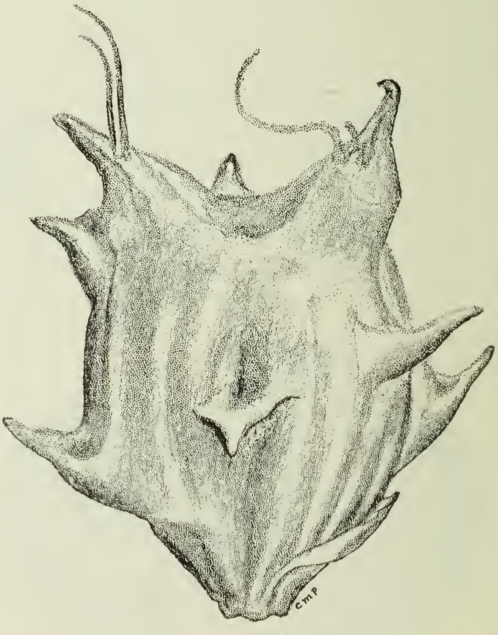


Fig. 135. Poverty Weed (Franseria tomentosa). x 12.

2. *Ragweed, Bitter-weed, Roman Wormwood*

(*Ambrosia* (*Tourn.*) *L.*)

Fruit enclosed in a nut-like involucre bearing 6, or rarely 7, stout projections or spines, usually 5 short spines and 1 long, central spine at the top, and the others just below the top or summit.

Key to Species

Seeds 2-3.5 mm. long.................................. 1..*A. artemisaefolia*
Seeds 5-10 mm. long.................................. 2..*A. trifida*

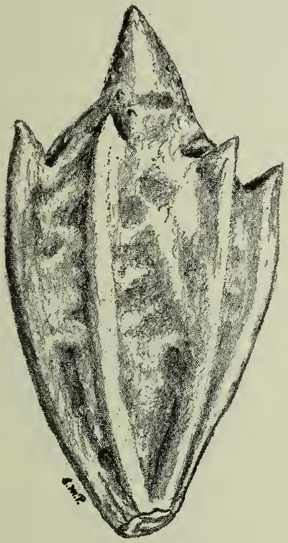


Fig. 136. Great Ragweed (Ambrosia trifida). x 12

1. GREAT RAGWEED, KINGHEAD (*Ambrosia trifida L.*) (Fig. 136).—Seeds white, cream-buff or honey-yellow in color, distinctly 5-6 ridged, the ridges ending in stout projections or spines near the summit; the apex of the seed terminates in a single stout projection which appears distinctly above the other spines; seeds variable in size usually 5-8 mm. long but occasionally 1- cm. long, broad at the top, narrow at the base.

2. RAGWEED, ROMAN WORMWOOD, HOG-WEED (*Ambrosia artemisaefolia A. Gray, Ambrosia elatior L.*) (Fig. 137).—Seeds neutral-gray to dark olive-gray in color, 5-7 ridged, either distinct or obscure, the ridges terminating in spines near the summit of the seed which itself tapers off into a spine or projection; seeds 2-3.5 mm. long, broad at the apex, narrower at the base.

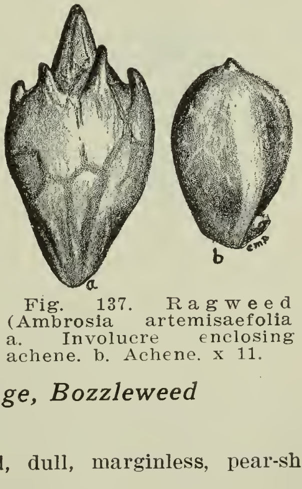


Fig. 137. Ragweed (Ambrosia artemisaefolia a. Involucre enclosing achene. b. Achene. x 11.

3. *Marsh Elder, Salt Sage, Bozzleweed*

(*Iva L.*)

Achenes compressed, mostly roughened, dull, marginless, pear-shaped. sides slightly concave; pappus absent.

Key to Species

Seeds ribbed .... 1..*Iva ciliata*

Seeds not ribbed
  Seeds usually angled, 1.5-2 mm. long...................... 2..*Iva xanthifolia*
  Seeds seldom angled, 2-3 mm. long......................... 3..*Iva axillaris*

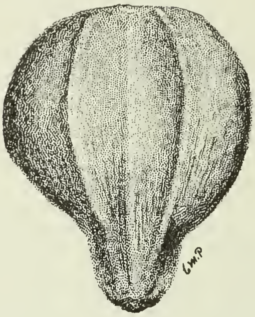


Fig. 138. Rough Marsh Elder (Iva ciliata). x 13.

1. ROUGH MARSH ELDER (*Iva ciliata Willd.*) (Fig. 138).—Seeds smoke-gray to deep grayish-olive in color, flattened, thin, each face marked with 2 or 3 ribs as long as the achene; seeds either broadly oval or pear-shaped, 2.5-3.5 mm. long, 2-3 mm. wide, in the widest part.

2. COMMON MARSH ELDER (*Iva xanthifolia Nutt.*) (Fig. 139).—Seeds neutral-gray to dark neutral-gray in color, somewhat rounded on each side, usually obscurely angled on one side; seeds uniformly cuneate in shape, 1.5-2 mm. long, 1-1.5 mm. wide, in the widest part, marked with numerous fine parallel lines as long as the seed.

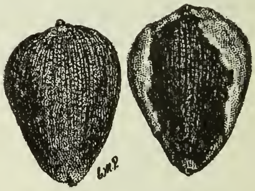


Fig. 139. Common Marsh Elder (Iva xanthifolia). x 12.

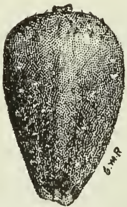


Fig. 140. Poverty Weed (Iva axillaris). x 11.

3. POVERTY WEED, SMALL-FLOWERED MARSH ELDER (*Iva axillaris Pursh.*) (Fig. 140).—Seeds deep mouse-gray to iron-gray in color, rounded on each face, not angled, uniformly cuneate in shape, 2-3 mm. long, 1.2-1.5 mm. wide, in the widest part.

33. THISTLE FAMILY

(*Compositae, Carduaceae*)

Fruit an achene; pappus consisting of bristles, awns, scales, teeth, or cup-like crown, or absent; seeds erect; endosperm absent; embryo straight.

Key to Genera

Seeds with a persistent pappus
Pappus feathery (plumose) .... 1..*Laciniaria*
Pappus not plumose
Pappus of 2-4 barbed teeth .... 2..*Bidens*
Pappus of 1-2 awl-shaped (subulate) teeth .... 3..*Ratibida*
Seeds without a persistent pappus
Seeds distinctly flattened, compressed, angled
Seeds with a light colored margin .... 4..*Achillea*
Seeds marginless
Seeds flattened but obscurely 4-angled
Seeds smooth, usually uniform in color .... 5..*Carduus*
Seeds rough or hairy, usually mottled or striped .... 6..*Helianthus*
Seeds mostly 4-5 angled or ribbed, smooth, irregular .... 7..*Grindelia*
Seeds not flattened; cylindrical in shape
Seeds smooth, 2-ribbed or without ribs .... 8..*Artemisia*
Seeds rough, 10-ribbed
Ribs white .... 9..*Chrysanthemum*
Ribs of the same color as the achene .... 10..*Anthemis*

1. *Blazing Star, Button Snakeroot*
(Lacinaria Hill., Liatris, Schreb.)

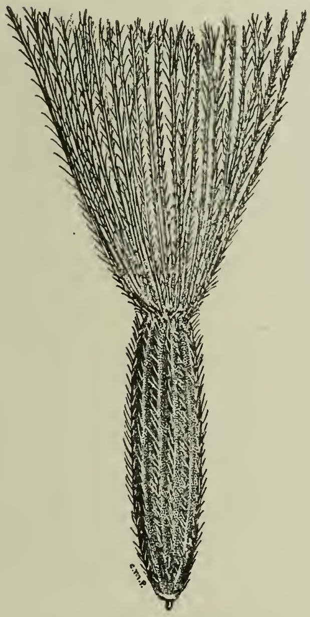


Fig. 141. Dotted Button Snakeroot (Laciniaria punctata). x 6.

Achenes 10-ribbed, slender, tapering from the top to the base; pappus of 1 or 2 circles or series of firm, equal, plumose hairs, or finely barbed bristles.

DOTTED BUTTON SNAKEROOT, BLAZING STAR (*Laciniaria punctata* (*Hook.*) *Kuntze*) (Fig. 141).—Seeds neutral-gray in color, 10-ribbed, hairy throughout, 6-8 mm. long; pappus plumose 8-10 mm. long.

2. *Beggar-ticks, Bur-marigold*
(Bidens L.)

Achenes either flat, obscurely 4-angled or almost circular in outline, wedge-shaped or oblong; pappus of 2-4 awns or teeth usually barbed downwardly or covered with bristly, stiff hairs.

BEGGARS-TICKS, STICKTIGHT (*Bidens frondosa L.*) (Fig. 142).—Seeds brown in color, flattened, slightly concave on one side, rough, each side with a central ridge as long as the seed; margins of the seeds barbed downwardly; pappus mostly of 2 downwardly barbed awns, 3-4 mm. long; seeds 5-7 mm. long.

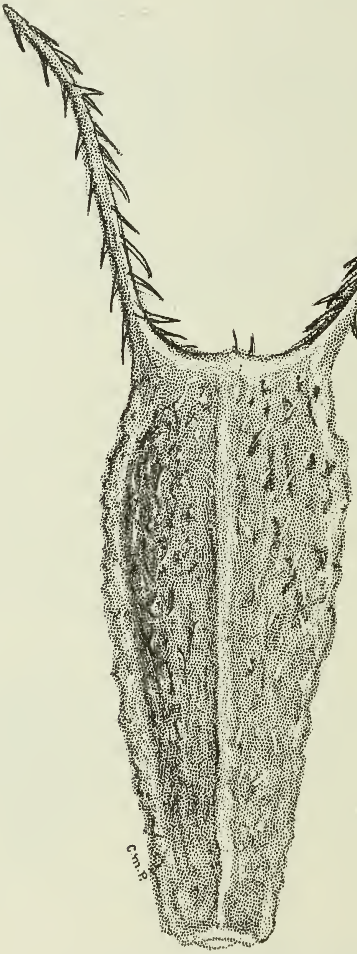


Fig. 142. Beggar's-ticks (Bidens frondosa). x 13.

3. Cone-flower

(*Ratibida Raf., Lepachys Raf.*)

Achenes short, flattened, with a broad margin, or wing which drops off at maturity; pappus of 1-2 awl-shaped teeth.

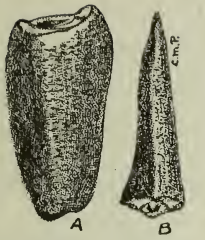


Fig. 143. Long-headed Cone-flower (Ratibida columnaris). A. Top view. B. Edge view. x 12.

LONG-HEADED OR PRAIRIE CONE-FLOWER (*Ratibida columnaris* (*Sims.*) *D. Don.*, *Ratibida columnifera* (*Nutt.*) *Woot. & Standl.*) (Fig. 143).—Seeds light neutral-gray to dark neutral-gray in color, flattended, a prominent ridge as long as the seed on one side, and both sides marked with 12-16 fine rounded ridges parallel to each other and as long as the seed; seeds 2-2.5 mm. long, 1-1.5 mm. wide.

4. *Yarrow, Milfoil*

(*Achillea* (*Vaillant*) *L.*)

Achenes oblong, flattened, distinctly margined; pappus wanting.

COMMON YARROW, MILFOIL (*Achillea millefolium L.*) (Fig. 144).—Seeds pallid neutral-gray to light olive-gray, flattened, oblong, margins light, nearly white in color; seeds 1.2-1.5 mm. long, .4-.7 mm. wide.

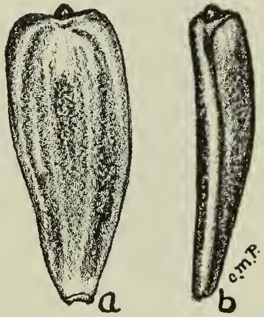


Fig. 144. Common Yarrow (Achillea millefolium). a. Top view. b. Edge view. x 30.

5. *Thistle, Common or Plumed Thistle*

(*Carduus L.*, *Cirsium* (*Tourn.*) *Hill.*)

Achenes oblong, flattened, seldom ribbed, occasionally obscurely 4-angled; pappus of plumose bristles united at the base into a ring, which drops away as a cap at maturity.

Key to Species

Seeds streaked with fine black lines........................ 1..*C. lanceolatus*
Seeds not streaked
  Seeds with a circular, yellow band at the top.............. 2..*C. discolor*
  Seeds uniformly brown in color
    Seeds 5-7 mm. long.. 3..*C. filipendulus*
    Seeds 2.5-3 mm. long... 4..*C. arvensis*

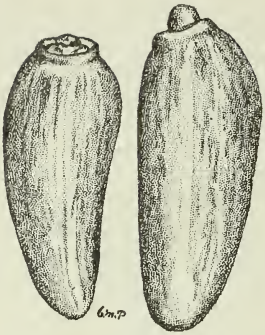


Fig. 145. Bur Thistle Carduus lanceolatus). x 12.

1. BUR THISTLE, SPEAR THISTLE, BULL THISTLE (*Carduus lanceolatus L., Cirsium lanceolatum (L.) Hill.*) (Fig. 145).—Seeds streaked with fine, broken, black lines, otherwise pale smoke-gray in color, 3.5-4 mm. long, 1.2-1.5 mm. wide in the widest part, oblong, obscurely flattened, straight or slightly curved (bent), apex with a distinct knob-like projection.

2. FIELD THISTLE (*Carduus discolor (Muhl.) Nutt., Cirsium discolor (Muhl.) Spreng.*) (Fig. 146).—Seeds shiny, light Dresden-brown in color, with a circular band of light yellow at the apex; seeds 3.5-4.5 mm. long, 1.5-2 mm. wide in the widest part, oblong, obscurely flattened, straight or slightly curved as in *C. lanceolatum;* apex with a knob-like projection.

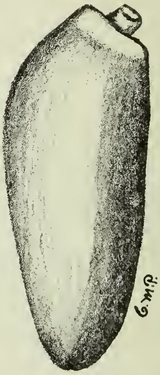


Fig. 146. Field Thistle Carduus discolor) x 12.

3. DROOPING THISTLE, FLODMAN'S THISTLE, (*Carduus filipendulus (Engelm.) Nels., Cirsium flodmanii (Rydb.) Arthur*) (Fig. 147).—Seeds shiny, brown in color, 5-7 mm. long, 1.5-2 mm. wide in the widest part, oblong, obscurely flattened, mostly slightly curved, seldom straight; apex with a proportionately smaller knob-like projection than *C. lanceolatum* or *C. discolor.*

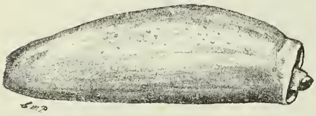
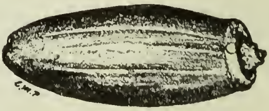


Fig. 147. Drooping Thistle (Carduus flodmanii). x 7.

4. CREEPING THISTLE, CANADA THISTLE (*Carduus arvensis (L.) Robs.) Cirsium arvense (L.) Scop.*) (Fig. 148).—Seeds shiny, buckthorn-brown to Dresden-brown in color, 2.5-3 mm. long, .7-1 mm. wide, slightly flattened, oblong, mostly straight, seldom curved; apex with a minute knob-like projection.



(Carduus arvensis). x 12.
Fig. 148. Creeping Thistle

6. *Sunflower, Ground Artichoke*

(*Helianthus L.*)

Achenes obscurely 4-angled, flattened or compressed, thick, oblong, or short wedge-shaped; pappus of 2 scales or awns, seldom persisting at maturity.

Key to Species

Seeds usually smooth, striped.............................. 1..*H. annuus*
Seeds usually hairy, mottled.............................. 2..*H. petiolaris*

1. Common Sunflower (*Helianthus annuus L., Helianthus lenticularis Dougl.*) (Fig. 149).—Seeds pale smoke-gray to drab-gray in color, mottled with broken, black lines or spots, smooth or hairy, the hairs more pronounced near the top; seeds 4-6 mm. long, 2.5-3 mm. wide, straight, mostly ovate to wedge-shaped.

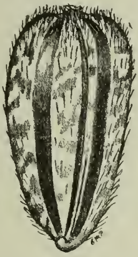


Fig. 149. Common Sunflower (Helianthus annuus). x 6.

2. Prairie Sunflower (*Helianthus petiolaris Nutt.*).. (Fig. 150).—Seeds wood-brown to buffy-brown in color, mottled though not as in *H. annuus*, but usually more hairy; achenes 4-6 mm. long, 2-2.5 mm. wide, straight, mostly ovate to wedge-shaped.

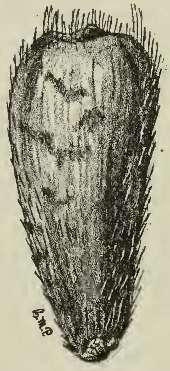


Fig. 150. Prairie Sunflower (Helianthus petiolaris). x 11.

7. *Gum Plant, Resin-weed, Tar-weed*

(*Grindelia Willd.*)

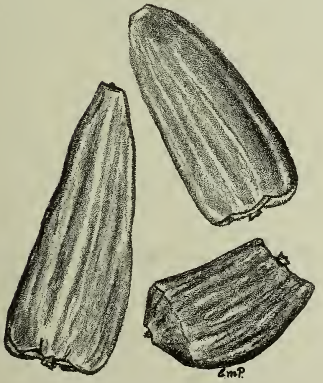


Fig. 151. Gum Plant (Grindelia sp.). x 11.

Achenes short, thick, (ending abruptly as though cut off transversely) 4-5 ribbed, flattened, smooth; pappus of 2-8 awns or bristles which fall off at maturity; achenes honey-yellow to chamois in color.

Gum Plant (*Grindelia sp.*) (Fig. 151).—In Colorado alone there are eleven known species[1] of Gum Plant.

The seeds of the several species have many characters in common. Up to the present time the seeds of these species have not been differentiated systematically.

[1] Flora of Colorado—Rydberg.

8. Wormwood, Sage-brush

(*Artemisia L.*)

Achenes narrowly cylindrical to oblong in outline, circular in cross-section, 2-ribbed or marked with slender grooves as long as the achenes; apex or summit rounded, usually bearing a disk.

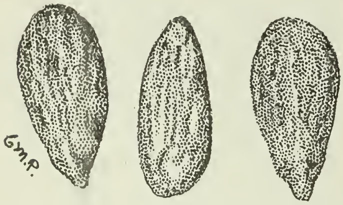


Fig. 152. Wormwood Sage (Artemisia frigida). x 40.

WORMWOOD SAGE, PASTURE SAGEBRUSH (*Artemisia frigida Willd.*) (Fig. 152).—Seeds Brussels-brown in color, circular in cross-section, oblong to cylindrical in shape, .5-.7 mm. long, slightly shiny, obscurely wrinkled lengthwise, and usually bearing a light colored disk at the summit.

9. Ox-eye Daisy

(*Chrysanthemum (Tourn.) L., Leucanthemum (Tourn.) Mill.*)

Achenes cylindrical, circular in cross-section, 10-ribbed; pappus wanting or reduced to a scaly cup.

OX-EYE DAISY (*Chrysanthemum leucanthemum L., Leucanthemum leucanthemum (L.) Rydb.*) (Fig. 153).—Seeds light wood-brown in color, cylindrical in shape, circular in cross-section, distinctly 10-ribbed; ribs white, parallel to each other and as long as the seed; seeds 1.5-2 mm. long, .4-.6 mm. wide at the apex.

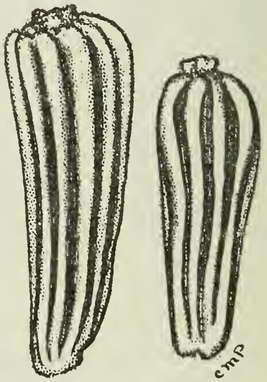


Fig. 153. Ox-eye Daisy (Chrysanthemum leucanthemum). x 28.

10. May-weed, Dog Fennel, Chamomile

(*Anthemis L., Maruta Cass.*)

Achenes nearly cylindrical or oblong in shape, 10-ribbed, marked with glandular, rounded projections which usually occur at the summit of the ridges; pappus wanting.

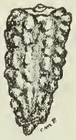


Fig. 154. May-weed (Anthemis cotula). x 15.

MAY-WEED, DOG FENNEL (*Anthemis cotula L., Maruta cotula (L.) D. C.*) (Fig. 154).—Seeds cinnamon-brown to clay color, 10-ribbed, summit of ridges covered thickly or sparingly with glandular, rounded projections; achenes 1-1.5 mm. long, .5 mm. wide.

34. CHICORY FAMILY

(*Cichoriaceae*)

Fruit an achene; pappus consisting of either scales, simple bristles (without subdivision or branches), plumose bristles, both simple and plumose bristles, or wanting; seeds erect; endosperm absent; radicle narrower than the cotyledons.

Key to Genera

Pappus consisting of scales reduced to a crown.................. 1..*Cichorium*
Pappus of hair-like bristles not plumose, often persistent
  Seeds flattened; seeds smooth or with minute blunt (not spiny) projections near the apex
    Seeds narrowed at the top, or beaked...................... 2..*Lactuca*
    Seeds square or even at the top as though cut off transversely.. 3..*Sonchus*
  Seeds not flattened
    Pappus usually persistent; seeds with the tip merely an indistinct point .... 4..*Lygodesmia*
    Pappus seldom persistent; seeds with the tip long, slender and distinct, 8-12 ribbed.............................. 5..*Taraxacum*

1. Chicory

(*Cichorium* (*Tourn.*) L.)

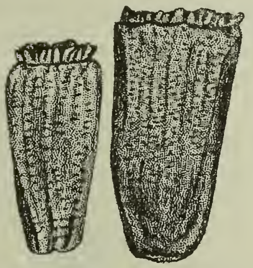


Fig. 155. Chicory (Cichorium intybus). x 12.

Achenes 5-angled or 5-ribbed, square or even at the top as though cut off transversely; the pappus consists of 2 series of short, blunt scales.

CHICORY, WILD SUCCORY (*Cichorium intybus L.*) (Fig. 155).—Seeds chamois to bone-brown in color; 2-2.5 mm. long, 1.2-1.5 mm. wide in the widest part, with a light colored, ring-like pappus at the apex; pappus more distinct on the darker seeds; other characters as given in the generic description.

2. Lettuce

(*Lactuca* (*Tourn.*) *L.*)

Achenes flattened, 1-5 veined or ribbed on each face, narrowed at the apex into a small disk bearing the hair-like pappus bristles, which fall separately.

Key to Species

Seeds 5-8 veined on each face................................ 1..*L. scariola*
Seeds mostly 3-veined on each face.......................... 2..*L. pulchella*

1. PRICKLY LETTUCE (*Lactuca scariola L.*) (Fig. 156).—Seeds buffy-brown in color, mostly 5-6 veined, mottled, flattened, slightly margined, hairy at the apex, 2.5-3 mm. long, .6-1 mm. wide.

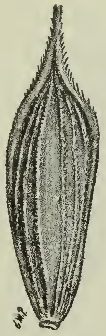


Fig. 156. Prickly Lettuce (Lactuca scariola). x 15

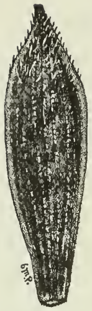


Fig. 157. Blue Lettuce (Lactuca pulchella). x 15.

2. BLUE LETTUCE (*Lactuca pulchella* (*Pursh.*) *DC.*) (Fig. 157).—Seeds deep mouse-gray in color, mostly 3-veined, slightly margined, flattened, mottled, rough throughout, 2.5-3 mm. long, .6-1 mm. wide, gradually tapering into a short beak; seeds less hairy than *L. scariola* but otherwise the same except in color.

3. Sow Thistle

(*Sonchus* (*Tourn.*) *L.*)

Achenes flattened, 10-20 ribbed, marked with blunt projections throughout, even or square at the apex as though cut off transversely; pappus of fine bristles mostly falling off together.

Key to Species

Seeds distinctly flattened
  Seeds roughened transversely .... 1..*S. oleraceus*
  Seeds not roughened, mostly 3-ribbed on each side .... 2..*S. asper*
Seeds only slightly flattened, 6-8 ribbed on each side; roughened
    transversely .... 3..*S. arvensis*

1. ANNUAL SOW THISTLE, COMMON SOW THISTLE (*Sonchus oleraceus L.*) (Fig. 158.—Seeds russet in color, flattened, slightly roughened transversely, 5-ribbed (one central rib and two on each side of the central rib parallel to it but close together giving a groove-like appearance on each side, thus 5-ribbed and 2-grooved), slightly margined, 2.5-3 mm. long, .7-1 mm. wide, in the widest part, narrowed at the base.

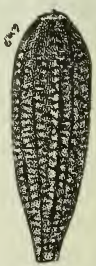


Fig. 158. Annual Sow-Thistle (Sonchus oleraceus). x 12.

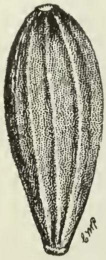


Fig. 159. Spiny-leaved Sow-Thistle (Sonchus asper). x 12.

2. SPINY-LEAVED, SPINY, OR SHARP-FRINGED SOW THISTLE (*Sonchus asper* (*L.*) *All.*) (Fig. 159).—Seeds russet in color, flattened, smooth, mostly 3-ribbed on each side, distinctly margined, blunt, thin, 2.5-3 mm. long, 1.2-1.4 mm. wide in the widest part, distinctly wider than *S. oleraceus* or *S. arvensis*.

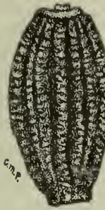


Fig. 160. Corn Sow-thistle (Sonchus arvensis). x 12.

3. CORN SOW THISTLE, FIELD SOW THISTLE, MILK THISTLE (*Sonchus arvensis L.*) (Fig. 160).—Seeds liver-brown in color, slightly flattened, roughened transversely, 6-8 ribbed on each side, ribs thick and rough; seeds 2-2.2 mm. long, 1-1.2 mm. wide, stout, blunt, margin indistinct.

4. *Prairie Pink, Sand Pink, Skeleton Weed*

(*Lygodesmia D. Don.*)

Achenes slender, either smooth, 6-8 ribbed or grooved, tapering slightly at the pappus end; pappus of numerous soft bristles as long or longer than the achene and usually persistent; beak or tip an indistinct point.

SAND PINK (*Lygodesmia juncea (Pursh.) D. Don.*) (Fig. 161).—Seeds ivory-yellow in color, slender, cylindrical in shape, nearly circular in cross-section, 8-12 ribbed, 5-7 mm. long, .5-.8 mm. wide.

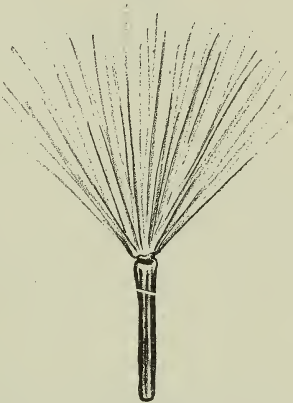


Fig. 161. Sand Pink (Lygodesmia juncea). x 3.

5. *Dandelion*

(*Taraxacum (Haller) Ludv., Leontodon L.*)

Achenes mostly spindle shaped or fusiform (swollen in the middle and narrowing toward each end), with a long, slender, distinct tip; achenes 8-12 ribbed, roughened with hard, sharp, small spines near the apex.

Key to Species

Seeds honey-yellow in color.............................. 1..*T. officinale*
Seeds claret-brown in color.............................. 2..*T. erythrospermum*

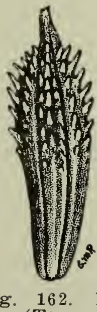


Fig. 162. Dandelion (Taraxacum officinale). x 11.

1. DANDELION, COMMON DANDELION, BLOW-BALL (*Taraxacum officinale Weber., Leontodon taraxacum L.*) (Fig. 162).—Seeds honey-yellow in color, mostly 10-12 ribbed, the ribs roughened with hard, sharp, small spines near the apex of the seed; in the middle area of the seed the ribs are roughened with short, hard (not spined) processes; the base of the seed is nearly smooth; seeds 3-3.5 mm. long, .5-1 mm. wide, nearly circular in cross-section.

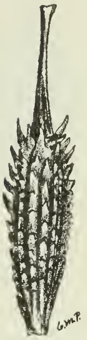


Fig. 163. Red-seeded Dandelion (Taraxacum erythrospermum). x 12.

2. RED-SEEDED DANDELION (*Taraxacum erythrospermum Andrz.*, *Leontodon erythrospermum (Andrz.) Eichw.*) (Fig. 163).—Seeds claret-brown in color, 8-12 ribbed, the ribs roughened with longer, more distinct spines at the apex than seeds of *T. officinale;* the remainder of the seed is usually roughened with short, hard processes gradually becoming smaller and extending to the base; seeds 2.5-3 mm. long, .5-.8 mm. wide, nearly circular in cross-section at apex, irregularly 4-sided at the base.

GLOSSARY

Achene, a small, dry, and 1-celled, 1-seeded, indehiscent fruit.
Acuminate, taper-pointed.
Acute, sharp-pointed but less so than acuminate.
Adnate, united; grown to.
Albumen, the substance, usually nutritive, surrounding the embryo of the seed.
Angled, having an angle or angles.
Annular, in the form of a ring.
Apex, the tip, point or summit of anything.
Apiculate, with a minute point, or ending in a short pointed tip.
Articulated, joined; having a node or joint.
Axil, the angle formed by a leaf or branch with the stem.
Awn, a bristle-like, or beard-like, appendage.
Barbed, with rigid points or short bristles, usually reflexed like the back of a fish-hook.
Beaked, ending in a beak or prolonged tip.
Bidentate, having two teeth.
Bifid, two-cleft.
Bloom, a surface coating.
Bract, a leaf, usually small, subtending a flower or flower cluster.
Calyx, the outer of two series of floral leaves.
Campanulate, bell-shaped.
Capsule, a dry, dehiscent fruit, composed of more than one carpel.
Carpel, a simple pistil, or one member of a compound pistil.
Caryopsis, the grain of grasses. A seed-like fruit with a thin pericarp adnate to the contained seed.
Circumscissile, transversely dehiscent, the top falling away as a lid.
Compressed, flattened, especially laterally.
Conduplicate, folded together lengthwise.
Connate, united; used especially of like structures joined from the start.
Cordate, heart-shaped.
Coriaceous, leathery in texture.
Crescent, shaped like the moon in its first quarter.
Crested, bearing an elevated appendage like a crest.
Cross-section, a section at right angles to the longer axis.
Crustaceous, hard and brittle in texture; crust-like.
Cuneate, wedge-shaped.

Dehisce, to open or split.

Distichous, in two vertical ranks, as the leaves of grasses.

Dorsal, on the back; surface of member turned away from the main axis.

Downy, covered with down, pubescence, or soft hairs.

Druplet, a small, fleshy fruit, with the inner portion hard and bony.

Enrolled, enveloped; inwrapped.

Evanescent, disappearing early.

Faceted, with small faces; as the facets of a diamond.

Falcate, scythe-shaped.

Fleshy, pulpy; succulent; plump.

Foliaceous, leaf-like in texture or appearance.

Follicle, a dry fruit consisting of a single carpel, dehiscing by a ventral suture.

Furrowed, grooved; wrinkled.

Fusiform, spindle-shaped; swollen in the middle and narrowing toward each end.

Glandular, with glands, or gland-like.

Globose, spherical or nearly so; globe-shaped.

Glume, the scaly bracts of the spikelets of grasses and sedges.

Granular, appearing as though covered by minute grains.

Hilum, the scar or area of attachment of the seed or ovule.

Hyaline, thin and translucent; nearly transparent.

Indurated, hardened.

Inflorescence, the flowering part of plants; the mode of arrangement.

Infolded, folded over; inwrapped; inclosed.

Involucre, a whorl of bracts subtending a flower-cluster or fruit, as in **Compositae.**

Irregular, not uniform.

Keeled, with a projecting ridge on a surface, like the keel of a boat.

Lateral, belonging to or borne on the side.

Lemma, the lower of the two bracts inclosing the flower in the grasses; sometimes called the flowering glume.

Lenticular, shaped like a double-convex lens.

Lobed, with rounded and projecting parts.

Mealy, appearing as though sprinkled with meal.

Membranous, thin and rather soft, and more or less translucent.

Micropyle, orifice of the ovule and corresponding point on the seed; the opening between the ovule or seed-coats.

Millimeter, the 1000th part of a meter—.03937 inches.

Napiform, turnip-shaped.

Nerved, with veins or slender ribs.

Notched, a v-shaped indentation or hollow.

Nutlet, diminutive of nut; a small nut.

Obtuse, blunt, or rounded.

Oval, broadly elliptical.

Ovary, the part of the pistil that contains the ovules.

Ovate, in outline like a longitudinal section of a hen's egg.

Ovoid, shaped like a hen's egg.

Ovule, the body which becomes the seed after fertilization.

Palet (Palea), the upper bract which, with the lemma, incloses the stamens and pistils of grass flowers.

Papillose, bearing minute, nipple-shaped projections.

Pappus, the modified calyx-limb in **Compositae** forming a crown of various character at the summit of the achene.

Pedicel, the stalk of a single flower in a flower cluster.

Pericarp, the wall of the fruit, or seed vessel; the ovary wall, consisting of three layers: exocarp, mesocarp, and endocarp.

Perigynium, the more or less infolded sac-like organ surrounding the pistil in **Carex.**

Pitted, marked with small depressions or pits.

Plumose, having fine hairs on each side, like the plume of a feather.

Protuberance, a swelling; a prominence.

Pyriform, pear-shaped.

Rachilla, the axis of the spikelet in grasses. The secondary axis.

Radial, spread from a common center.

Raphe, a seam or suture. That part of the funicle united to the integument. forming a ridge along the ovule.

Reniform, kidney-shaped.

Reticulated, in the form of network.

Ribbed, with ribs, as the primary or prominent vein of a leaf.

Ridge, a raised line or strip.

Rugose, wrinkled.

Scales, minute, thin, membraneous, chaffy or woody bracts.

Scarious, thin, dry and translucent.

Scurfy, with thin, dry scales adhering to the surface.

Spikelet, diminutive of spike; especially applied to flower-clusters of grasses.

Subglobose, nearly, or imperfectly, globular.

Subulate, awl-shaped.

Sub-terminal, arising below the summit or apex.

Suture, a line of splitting or opening.

Tailed, having an appendage or tail.

Teeth, projecting marginal points.

Terminal, end, or extremity.

Tip, the point, extremity, or upper or top part.

Translucent, partially transparent.

Transverse, across; in a right and left line.

Truncate, ending abruptly, as if cut off transversely.

Turbinate, top-shaped.

Utricle, a 1-seeded fruit with a bladder-like covering.

Valve, one of the pieces into which a dehiscent pod, or any similar body, splits.

Vein, one of the vascular bundles forming the framework of a leaf.

Ventral, on the lower surface.

Winged, with any membraneous expansion.

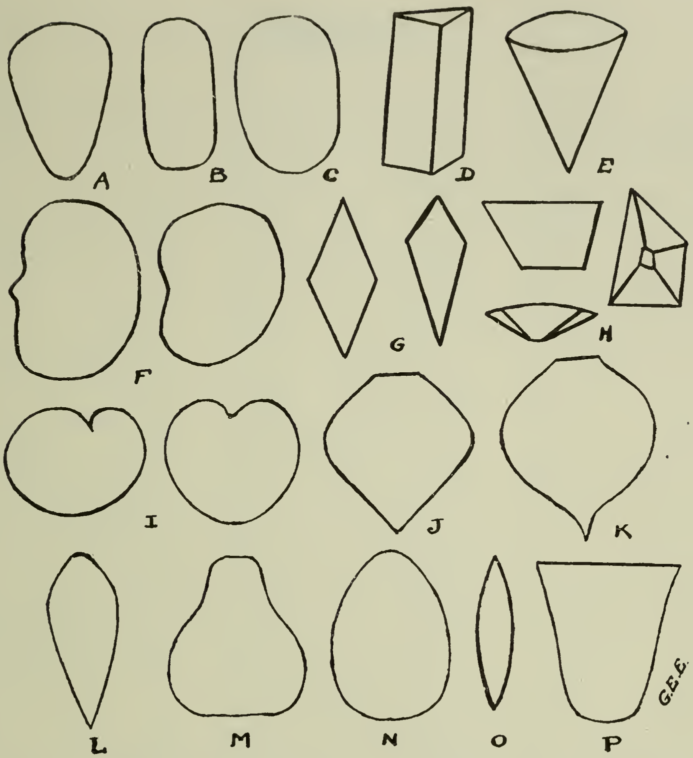


Fig. 164. Seed shapes referred to in family, generic and specific keys. A. Cuneate. B. Oblong. C. Oval. D. Prismatic. E. Conical. F. Reniform. G. Fusiform. H. Frustrum of a spherical pyramid. I. Cordate. J. Turbinate. K. Napiform. L. Acuminate. M. Pyriform. N. Ovate. O. Lenticular. P. Campanulate.

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Bulletin 261 January, 1921

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

Report of

Potato Investigations

By the United States Department of Agriculture at the Greeley, Colorado, Experiment Station in Cooperation with the County Commissioners of Weld County and the Colorado Agricultural Experiment Station

29 1945

By CHARLES F. CLARK
Horticulturist

View of experimental plats with the station buildings in the background.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1921

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Report of
Potato Investigations

By CHARLES F. CLARK*
Horticulturist

INTRODUCTION

The Colorado Potato Experiment Station, which is located at Greeley, Colorado, was established in 1915 for the purpose of conducting "experiments to improve the potato industry of Colorado, for investigating the nature and causes of the potato disease prevalent in the state of Colorado and for finding remedial or preventive measures therefor, for studying cultural and crop rotation factors in their relation to potato production, for introducing and developing new and improved varieties of potatoes, and for conducting other studies for the benefit of the potato industry."†

The work of the station is conducted by the United States Department of Agriculture. Cooperating with the Federal Government are Weld county, which, thru the County Commissioners, has furnished the land and laboratory building, and the state of Colorado, which has furnished funds, disbursed thru the State Agricultural College, for equipment. The general supervision of the station, together with the potato investigations, exclusive of those which relate to diseases, are under the direction of the office of Horticultural and Pomological Investigations. The pathological work is conducted by the office of Cotton, Truck and Forage Crop Disease Investigations. Insect investigations have recently been started by the Bureau of Entomology.

SOIL, ROTATION AND GENERAL METHODS

The type of soil on which the station farm is located is a rather heavy clay loam designated as the Fort Collins loam.‡ On the part of the farm which is devoted to the potato experiments a four-year rotation is maintained which consists of potatoes one year, grain one year and alfalfa two years. Lack of space does not permit a longer period in alfalfa which would be desirable. The alfalfa ground which is to be planted to potatoes the following year is plowed shallow, or "crowned," late in the fall. In the spring the soil is pulverized by harrowing as early as moisture conditions will permit. In April or the first of May, the land is manured and plowed to a depth of eight or nine inches after which it is harrowed and leveled.

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*Office of Horticultural and Pomological Investigations, Bureau Plant Industry, U. S. Department of Agriculture.

†Extract from terms of lease, March 13, 1915.

‡Field Operations of the Bureau of Soils, 1904.

Practically all the potatoes used for seed are treated before planting, using a solution of corrosive sublimate containing one pound of the chemical to 120 gallons of water. Planting is started from the first to the fifth of June, the two-man type of planter being used for the machine work. Cultivation is begun as soon as planting is finished and continued until the vines become too large for further operations with the cultivator. With the exception of special irrigation experiments and a few non-irrigated rows the potatoes are irrigated at such times as their appearance and the condition of the soil would indicate that water was needed, the time for starting and the frequency of application depending upon climatic conditions. On the experimental plats the water is distributed by means of wooden tubes having an orifice of one inch in diameter which are placed in the ditch bank, one tube to each row. This system greatly facilitates the uniform application of water which is essential for accurate experimental work.

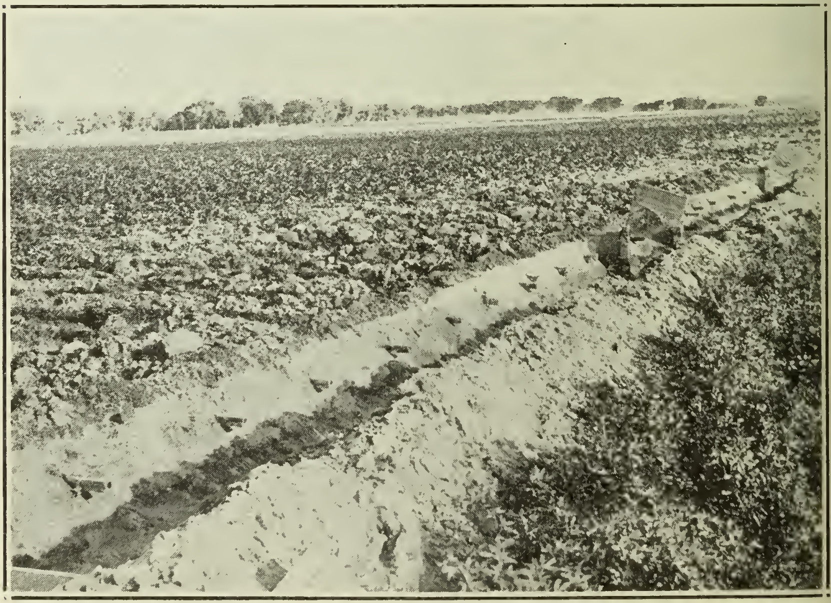

Fig. 1—Irrigation system used on experimental plats, showing tubes placed in ditch bank to secure a uniform distribution of water.

EXPERIMENTS

While the work of the station has been in progress for four seasons some of the experiments have not been conducted during the entire period, therefore it will be impossible in many cases to draw definite conclusions, which can be reached only after a long series of investigations under a comparatively wide range of climatic conditions. It is believed, however, that the results obtained up to the present time will be of value in pointing out the nature and scope of the work, the progress that has been made and tentative conclusions, if any, which may be drawn.

VARIETY TESTS

The area unit adopted for these tests was a four-row plat 240 feet long in 1915, 1916 and 1917, and 246 feet long in 1918. All tests were duplicated, the second series being planted as soon as the planting of the first series was completed. In 1915 seed of most of the varieties was obtained from two sources and planted side by side for comparison. In 1916 and subsequent years, purchased seed was compared with that which had been grown at the station one or more years. As this phase of the work increased from year to year it was necessary to gradually eliminate the varieties of least importance in the district because of lack of space.

The field weights were obtained as the crop was hauled into the storage cellar. After weighing, the potatoes were stored either in sacks or emptied in bins, the product of each plat being kept separate except that lots from corresponding plats of the two series were put together. During the winter they were graded by means of a sorter of the shaker type having a screen with one and seven-eighths inch meshes, those going over the screen being designated as marketable and those going thru as culls. The difference between the field weights and cellar weights after sorting, including both marketable and culls, constitutes the loss during storage.

In cases where seed was saved for the next season's planting it was picked out at the time of sorting. The badly diseased hills, however, especially those seriously effected by Rhizoctonia or Fusarium, were dug by hand and discarded early in the fall before the vines were damaged by frost but after the tubers had nearly completed their growth. The weights of these hills were recorded and added to the field weights obtained at the time the main crop was dug. Since these hills were discarded and not included in the

TABLE 1

Variety Test, 1915

VARIETY	Source of seed	Yield per acre, field weights			Weights after sorting total yield of series 1 and 2			Field weights, Series 1 and 2	Loss	Marketable
		Series 1	Series 2	Average	Marketable	Culls	Total			
		Bushels	Bushels	Bushels	Pounds	Pounds	Pounds	Pounds	Per cent	Per cent
Pearl	Colorado, irrigated	217.8	306.8	262.3	2,085	400	2,485	2,781	10.6	83.9
Pearl	Colorado, dry land	345.1	374.3	359.7	2,408	276	2,684	2,854	6.0	89.7
Pearl	Wisconsin	330.0	375.3	352.7	2,325	214	2,539	2,798	9.3	91.6
Peoples	Colorado	305.5	336.3	320.9	2,191	198	2,389	2,546	6.2	91.7
Peoples	Idaho	287.6	303.5	295.6	2,028	200	2,228	2,345	5.0	91.0
Rural New Yorker	Colorado	334.5	336.8	335.7	2,375	136	2,511	2,663	5.7	94.6
Rural New Yorker	Wisconsin	289.9	310.1	300.0	2,049	140	2,189	2,380	8.0	93.6
Green Mountain	Minnesota	366.0	335.5	350.8	2,344	203	2,547	2,783	8.5	92.0
Green Mountain	Wisconsin	409.9	432.8	421.4	2,912	243	3,155	3,343	5.6	92.3
Charles Downing	Colorado	252.3	256.4	254.4	1,778	123	1,901	2,018	5.8	93.5
Charles Downing	Idaho	288.4	275.3	281.9	1,651	475	2,126	2,236	4.9	77.7
Early Ohio	Minnesota	153.8	108.1	131.0	764	179	943	1,039	9.2	81.0
Late Ohio	Colorado	265.9	303.8	284.9	1,708	371	2,079	2,260	8.0	82.2
Irish Cobbler	Minnesota	217.8	193.1	205.5	1,301	222	1,523	1,630	6.6	85.4
Irish Cobbler	Wisconsin	239.0	257.6	248.3	1,604	250	1,854	1,970	5.9	86.5
Peachblow	Colorado	384.7	401.3	393.0	2,550	326	2,876	3,118	7.8	88.7
Russet Burbank	Colorado	343.6	336.8	340.2	2,157	317	2,474	2,699	8.3	87.2
Russet Burbank	Idaho	361.0	347.6	354.3	2,314	347	2,661	2,811	5.3	87.0
Garnet Chili[1]	Maine	272.2	274.3	273.3	924	82	1,006	1,084	7.2	91.8
Averages		298.2	308.7	303.5	1,972	248	2,220	2,387	7.0	88.5

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[1] Each plat of this variety consisted of only two rows.

cellar weights they were deducted from the total field weights before calculating the loss during storage. The yields of the different varieties, both before and after sorting, as well as the losses during storage and the per cent of marketable tubers, for the years 1915 to 1918 inclusive, are given in tables 1 to 4.

In determining the merits of the different varieties for commercial production a number of features must be considered. While a good yield is essential it is equally important that tubers of good shape and cooking quality be produced and that the variety be sufficiently resistant to diseases to prevent rapid deterioration. In 1915, the year in which the greatest number of varieties was grown, the largest yield was obtained from the Green Mountain plats which were grown from the Wisconsin seed. The tubers, however, were of such inferior shape as to be scarcely fit for market. While the Peachblow ranked next in yield the large tubers of this variety showed the objectionable feature of cracking open during the process of growth. In 1916 this variety, grown from seed produced at the station the preceding year, showed a decided falling off in yield which was attributed largely to so-called "running out" as the result of pathological troubles. Altho fairly good yields have been obtained from the Russet Burbank, the tendency which this variety possesses of producing a second growth, or "knobbed" tubers, renders it undesirable for conditions which obtain at the station. While the three varieties mentioned above produce good crops of excellent quality in localities to which they are adapted, they are apparently

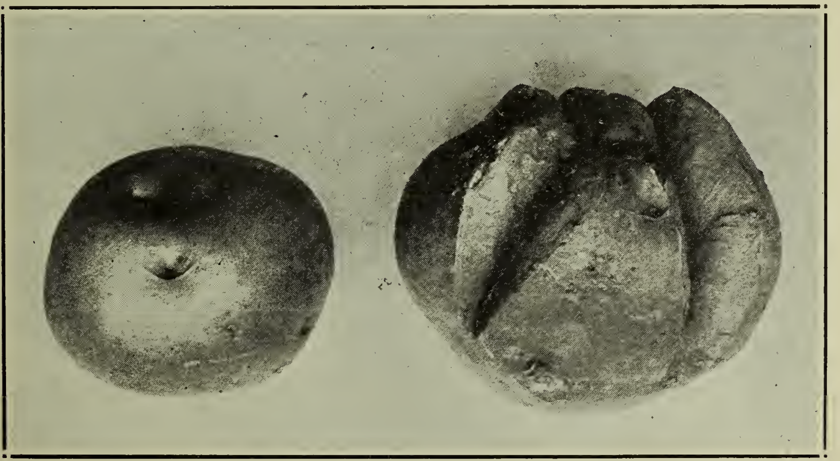

Fig. 2—Tubers of the Peachblow variety: left, good type of tuber grown under favorable conditions; right, cracked tuber, a type frequently found in the larger sizes when grown under conditions unsuited to this variety.

TABLE 2

Variety Test, 1916

VARIETY	Source of seed	Year first grown at station	Yield per acre, field weights			Weights after sorting, total yield of series 1 and 2			Field weights, Series 1 and 2	Loss	Marketable
			Series 1	Series 2	Average	Marketable	Culls	Total			
			Bushels	Bushels	Bushels	Pounds	Pounds	Pounds	Pounds	Per cent	Per cent
Pearl	Colorado, irrigated	1916	295.9	282.8	289.4	1,619	140	1,759	2,296	23.4	92.0
Pearl	Colorado, irrigated	1915	354.4	325.4	339.9	2,096	190	2,286	2,697	15.2	91.7
Pearl	Colorado, dry land	1916	371.1	289.9	330.5	2,088	172	2,260	2,622	13.8	92.4
Pearl	Colorado, dry land	1915	362.7	314.1	338.4	2,106	189	2,295	2,685	14.5	91.8
Pearl	Wisconsin	1916	364.0	329.0	346.5	2,186	176	2,362	2,749	14.1	92.5
Pearl	Wisconsin	1915	332.0	309.1	320.6	2,026	205	2,231	2,543	12.3	90.8
Rural New Yorker	Colorado	1916	316.1	271.5	293.8	2,075	76	2,151	2,331	7.7	96.5
Rural New Yorker	Colorado	1915	337.8	310.8	324.3	2,270	127	2,397	2,573	6.8	94.7
Rural New Yorker	Wisconsin	1916	347.9	316.4	332.2	2,265	88	2,353	2,635	10.7	96.3
Rural New Yorker	Wisconsin	1915	310.3	268.5	289.4	2,031	70	2,101	2,296	8.5	96.7
Russet Rural	Michigan	1916	300.5	286.6	293.6	2,096	77	2,173	2,329	6.7	96.5
Charles Downing	Idaho	1916	283.3	292.4	287.9	1,792	443	2,235	2,284	2.1	80.2
Charles Downing	Idaho	1915	308.5	291.7	300.1	1,938	401	2,339	2,381	1.8	82.9
Early Ohio	Minnesota	1916	198.9	198.9	198.9	1,324	218	1,542	1,578	2.3	85.9
Early Ohio	Minnesota	1915	249.8	258.4	254.1	1,671	299	1,970	2,016	2.3	84.8
Late Ohio	Colorado	1916	302.0	285.6	293.8	1,889	394	2,283	2,331	2.1	82.7
Late Ohio	Colorado	1915	317.1	306.8	312.0	2,027	391	2,418	2,475	2.3	83.8
Irish Cobbler	Wisconsin	1916	310.3	296.7	303.5	2,233	146	2,379	2,408	1.2	93.9
Irish Cobbler	Wisconsin	1915	315.9	300.2	308.1	2,166	192	2,358	2,444	3.5	91.9
Peachblow	Colorado	1915	290.9	209.2	250.1	1,742	165	1,907	1,984	3.9	91.3
Russet Burbank	Idaho	1916	295.2	224.6	259.9	1,428	447	1,875	2,062	9.1	76.2
Russet Burbank	Idaho	1915	323.9	241.2	282.6	1,646	415	2,061	2,242	8.1	79.9
Averages			313.1	282.3	297.7	1,942	228	2,170	2,362	7.8	89.3

TABLE 3

Variety Test, 1917

VARIETY	Source of seed	Year first grown at station	Yield per acre, field weights			Weights after sorting, total yield of series 1 and 2			Field weights, Series 1 and 2	Loss	Marketable
			Series 1	Series 2	Average	Marketable	Culls	Total			
			Bushels	Bushels	Bushels	Pounds	Pounds	Pounds	Pounds	Per cent	Per cent
Pearl	Colorado, irrigated	1917	364.0	369.5	366.8	2,199	276	2,475	2,910	14.9	88.8
Pearl	Colorado, irrigated	1916	355.9	321.9	338.9	1,986	293	2,279	2,689	15.2	87.1
Pearl	Colorado, irrigated	1915	362.0	350.6	356.3	2,119	317	2,436	2,827	13.8	87.0
Pearl	Colorado, dry land	1917	434.6	427.3	431.0	2,907	240	3,147	3,419	8.0	92.4
Pearl	Colorado, dry land	1916	371.6	365.5	368.6	2,313	295	2,608	2,924	10.8	88.7
Pearl	Colorado, dry land	1915	353.9	331.5	342.7	2,024	228	2,252	2,719	17.2	89.9
Pearl	Wisconsin	1917	402.6	428.3	415.5	2,731	295	3,026	3,296	8.2	90.3
Pearl	Wisconsin	1916	348.9	338.3	343.6	2,129	265	2,394	2,726	12.2	88.9
Pearl	Wisconsin	1915	338.8	339.3	339.1	2,096	262	2,358	2,690	12.3	88.9
Rural New Yorker	Colorado	1917	373.8	366.0	369.9	2,453	98	2,551	2,935	13.1	96.2
Rural New Yorker	Colorado	1916	402.3	386.9	394.6	2,797	70	2,867	3,131	8.4	97.6
Rural New Yorker	Colorado	1915	397.5	386.2	391.9	2,821	72	2,893	3,109	6.9	97.5
Rural New Yorker	Wisconsin	1917	413.4	397.5	405.5	2,859	67	2,926	3,217	9.0	97.7
Rural New Yorker	Wisconsin	1916	404.6	381.4	393.0	2,811	64	2,875	3,118	7.8	97.8
Rural New Yorker	Wisconsin	1915	395.8	376.6	386.2	2,804	66	2,870	3,064	6.3	97.7
Rural New Yorker	New York	1917	396.5	402.6	399.6	2,835	81	2,916	3,170	8.0	97.2
Russet Rural	Michigan	1917	387.2	376.4	381.8	2,714	92	2,806	3,029	7.4	96.7
Russet Rural	Michigan	1916	374.6	351.4	363.0	2,575	68	2,643	2,880	8.2	97.4
Charles Downing	Idaho	1915	261.9	279.1	270.5	1,932	194	2,126	2,146	.9	90.9
Late Ohio	Colorado	1915	312.1	302.5	307.3	2,120	296	2,416	2,438	.9	87.7
Irish Cobbler	Wisconsin	1917	282.1	297.5	289.8	2,116	150	2,266	2,299	1.4	93.4
Averages			368.3	360.8	364.6	2,445	180	2,625	2,892	9.1	92.8

TABLE 4

Variety Test, 1918

VARIETY	Source of seed	Year first grown at station	Yield per acre, field weights			Weights after sorting, total yield of series 1 and 2			Field weights, Series 1 and 2	Loss	Marketable
			Series 1	Series 2	Average	Marketable	Culls	Total			
			Bushels	Bushels	Bushels	Pounds	Pounds	Pounds	Pounds	Per cent	Per cent
Pearl	Colorado, irrigated	1918	322.3	366.5	344.4	4,691[1]	811	5,502	5,943	7.4	85.3
Pearl	Colorado, dry land	1918	388.9	384.3	386.6						
Pearl	Wisconsin	1918	317.8	337.5	327.7	2,079	312	2,391	2,552	6.3	87.0
Pearl	Wisconsin	1917	309.0	324.0	316.5	2,059	230	2,289	2,506	8.7	90.0
Pearl	Wisconsin	1916	283.6	305.3	294.5	1,858	226	2,084	2,304	9.5	89.2
Pearl	Wisconsin	1915	252.9	292.7	272.8	1,667	209	1,876	2,070	9.4	88.9
Rural New Yorker	Colorado	1918	240.6	282.9	261.8	1,688	158	1,846	1,946	5.1	91.4
Rural New Yorker	Colorado	1917	315.6	322.5	319.1	2,232	142	2,374	2,539	6.5	94.0
Rural New Yorker	Colorado	1916	315.9	332.8	324.4	2,149	163	2,312	2,595	10.9	93.0
Rural New Yorker	Colorado	1915	290.0	311.9	301.0	2,179	128	2,307	2,387	3.4	94.4
Rural New Yorker	Wisconsin	1918	283.4	312.9	298.2	3,928[1]	248	4,176	4,579	8.8	94.1
Rural New Yorker	New York	1918	283.6	292.5	288.1						
Averages			300.3	322.2	311.3	2,044	219	2,263	2,452	7.6	90.7

[1] Because of lack of storage space the crop from the seed from the different sources was not kept separate.

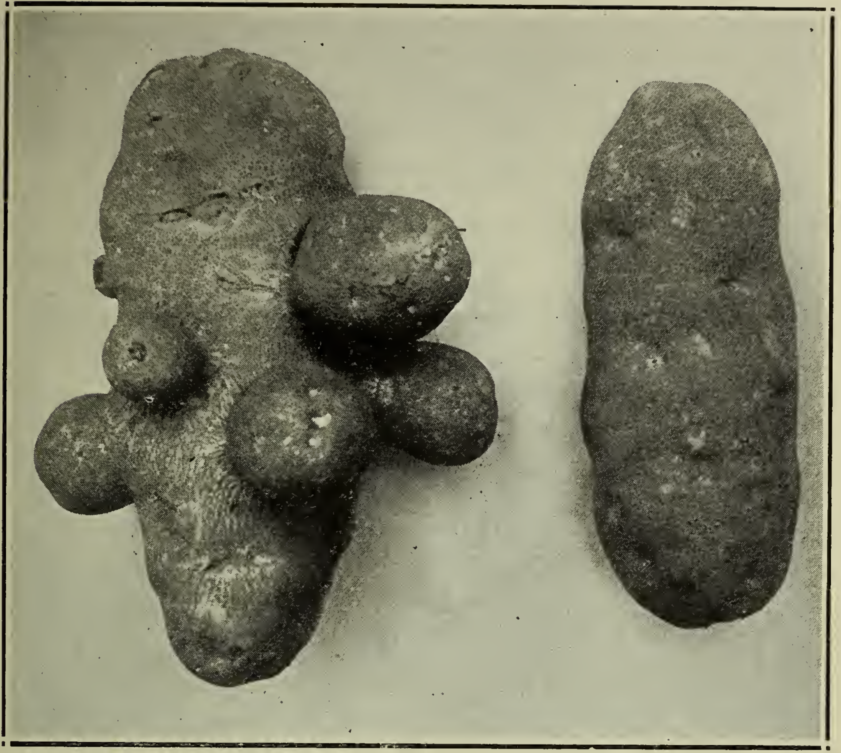

Fig. 3—Tubers of the Russet Burbank variety: right, good type of tuber grown under favorable conditions; left, undesirable type characteristic of this variety when grown on the heavier soils.

unsuited to conditions in the Greeley district. Of the varieties included in this test the Pearl and Rural New Yorker have given the most satisfactory results. While the total yields of the latter variety have in general been somewhat lower than those of the Pearl, this variety produces a much smoother type of tuber and a lower percentage of culls.

Comparing the three early varieties, Early Ohio, Irish Cobbler and Charles Downing, we find the yield of the Early Ohio considerably below that of the other two. This variety also has a tendency to produce rough, knobbed tubers under favorable conditions. On the other hand it ranks very high in cooking quality. The Irish Cobbler is apparently not suited to local conditions as the vines have invariably showed lack of vigor and the tubers elongated with very deep eyes. The Charles Downing produces tubers of good quality tho the percentage of culls is relatively high. The tubers of the Late Ohio appear to be identical with those of the Early Ohio.

This has led many to believe that the two names represent only a single variety. This is not the case as the Late Ohio produces a larger growth of vines differing in many respects from those of the Early Ohio, is later in maturing and produces a larger yield.

SOURCE OF SEED

With many of the varieties used in the variety test the seed was secured from two or more sources so that comparisons may be made which will show to some extent the relation of locality to quality of seed. The data bearing on this point are brot together in Table 5.

In 1915 there were three comparisons between Colorado irrigated and Idaho seed in two of which larger yields were obtained from seed from the last named source. The averages are also slightly in favor of the Idaho seed tho the differences are so small that they may be regarded as within the limits of error. The Irish Cobbler and Green Mountain varieties both produced larger yields from the Wisconsin seed than from that which was obtained from Minnesota. These comparisons are, however, few in number and for only

TABLE 5

Yields from Seed Obtained from Different Sources. Summarized from Tables 1, 2, 3 and 4. Bushels Per Acre, Field Weights.

VARIETY	Year of test	Source of seed					
		Colorado dry land	Colorado irrigated	Idaho	Minnesota	Wisconsin	New York
Peoples	1915	.....	320.9	295.6	.....	.....	.....
Green Mountain	1915	.....	.....	.....	350.8	421.4	.....
Charles Downing	1915	.....	254.4	281.9	.....	.....	.....
Irish Cobbler	1915	.....	.....	.....	205.5	248.3	.....
Russet Burbank	1915	.....	340.2	354.3	.....	.....	.....
Average		.....	305.2	310.6	278.2	334.9	.....
Pearl	1915	359.7	262.3	.....	.....	352.7	.....
Pearl	1916	330.5	289.4	.....	.....	346.5	.....
Pearl	1917	431.0	366.8	.....	.....	415.5	.....
Pearl	1918	386.6	344.4	.....	.....	327.7	.....
Average of Pearl		377.0	315.7	.....	.....	360.6	.....
Rural New Yorker	1915	.....	335.7	.....	.....	300.0	.....
Rural New Yorker	1916	.....	293.8	.....	.....	332.2	.....
Rural New Yorker	1917	.....	369.9	.....	.....	405.5	399.6
Rural New Yorker	1918	.....	261.8	.....	.....	298.2	288.1
Average of Rural New Yorker, 1915-1918			315.3	.....	.....	334.0	.....
Average of Rural New Yorker, 1917-1918			315.9	.....	.....	351.9	343.9

a single season. This does not eliminate the possible influence of seasonal variations on the original seed stock which may be reflected in the following crop.

The Pearl seed was obtained from three sources and the data cover a period of four years. With the exception of one season when the dry land seed was badly diseased, stock from this source has given the best results, with the Wisconsin seed next in order, the yields of both being considerably above those obtained from the Colorado irrigated seed. The largest yields of the Rural New Yorker were obtained from the Wisconsin stock, with yields from the New York state seed closely following. A study of the yields of all the varieties included in this experiment shows very consistently the relatively high quality, as measured by the crops produced, of the Colorado dry land and Wisconsin seed.

LOSSES DURING STORAGE

These losses, which are shown for the different years in next to the last column in tables 1, 2, 3, and 4, respectively, include the decrease in weight due to evaporation from the surface of the tubers and from respiration, also the weight of dirt which adhered to the tubers in digging but which was largely removed during the process of sorting. In 1917 severe freezes before all the potatoes

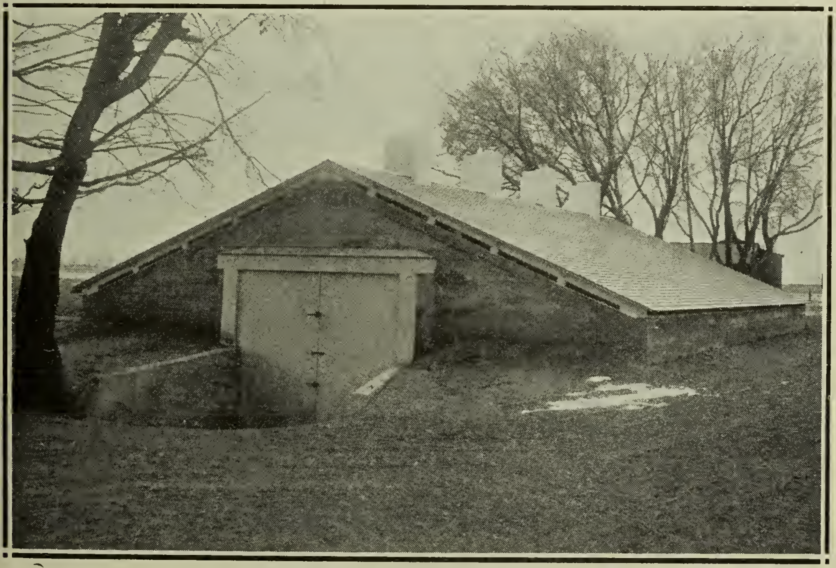

Fig. 4—Potato storage house at experiment station.

were dug caused some frost injury which resulted in losses in weight in addition to the sources enumerated above.

The potatoes were placed in the storage cellar and the field weights obtained the day on which they were dug. The sorting was done during the winter, usually between the middle of December and the middle of February, after which the cellar weights were recorded. As soon as the potatoes were placed in storage the temperature of the cellar was lowered as rapidly as possible until a uniform temperature slightly below 40 degrees F. was reached. The thermograph charts show that during the fall and winter seasons covered by the experiments a temperature range within the limits of 34 to 40 degrees F. was maintained from the last of November to the last of March. The relative humidity fluctuated between 80 and 90 per cent, depending upon the frequency of ventilation, except that for short periods when the ventilators were open, percentages below 60 were sometimes reached.

During the years 1915, 1916 and 1918, when there was practically no field frost, the average losses during the storage period were very uniform varying only from 7.0 to 7.8 per cent. The greater average loss in 1917, 9.1 per cent, is attributed largely to the effect of frost injury before digging in the case of some of the late varieties, particularly the Pearl. While the per cent of frosted tubers was comparatively small the loss in weight from those which were damaged was considerable. The wide variation in losses from the different varieties during a given season does not necessarily indicate that the magnitude of the loss may be a varietal characteristic tho the losses may be associated with certain relations of the variety to conditions. For example, the relatively small losses of the early varieties may be explained by the fact that they were dug early in the season, usually when the ground was dry so that practically no dirt adhered to them. The Pearl, as grown on the comparatively heavy soil of the station farm, produces a large percentage of knobbed tubers which carry more dirt into the cellar than the smooth tubers of the Rural New Yorker. In 1917 three of the varieties, Charles Downing, Late Ohio and Irish Cobbler, were not only almost entirely free from dirt when dug but were sorted and the cellar weights obtained the second day after digging thus affording little opportunity for loss from this source. On the other hand in 1916 the digging of the Pearl and Rural New Yorker was delayed by rains until it was so late that no time could be allowed for the ground to dry out, consequently the tubers and the soil adhering to them were wet which resulted in relatively large losses in storage. Further evidence of the excessive shrinkage which follows the digging from wet soil is shown in the cooperative experiments at Carbondale where conditions obtained similar to those described above. The average loss from 900 bushels, including the Peachblow and Russet Burbank varieties, was 16.3 per cent.

To show the large amount of dirt that may be carried to the cellar on the tubers, the data which were obtained from the plats whose crop was stored in sacks have been brot together and the percentages determined. In these instances the potatoes, which were still in the sacks in which they were taken from the field, were weighed just before sorting. After sorting they were weighed again, the difference between the two weighings representing the amount of dirt which had been removed. The results are shown in Table 6.

TABLE 6

Storage Losses Due to Dirt Which Adhered to the Tubers at the Time of Digging.

Variety	Source of Data	Field Weights Pounds	Weight Before Sorting Pounds	Weight After Sorting Pounds	Total Loss During Storage Per Cent.	Loss Due to Dirt Per Cent.
Pearl...............	Variety test. New, 1-, 2- and 3-year old Wisconsin seed............	9432	9089	8640	8.4	4.9
Pearl...............	Irrigation experiment. Early and late irrigated plats.........	5708	5514	5325	6.7	3.4
Rural New Yorker...	Variety test. New and 1-year old Colorado seed.	4485	4333	4220	5.9	2.6
Rural New Yorker...	Irrigation experiment. Early and late irrigated plats.........	4855	4712	4545	6.4	3.5
Averages........	....	....	....	....	6.9	3.6

Of the 24,480 pounds taken from the field representing the crop of two varieties from 20 plats, 918 pounds, or 3.6 per cent, was dirt, the weight of which constituted approximately one-half the total shrinkage. It should be borne in mind, however, that the amount of dirt which adheres to the tubers varies greatly with the variety, the character of the soil and its condition at the time of digging with respect to moisture.

In order to determine the internal losses of the tubers during storage potatoes of the Rural New Yorker variety, which were practically free from dirt and which had been in the storage cellar for over a month, were placed in barrels where they remained undisturbed during the remainder of the storage period. The barrels were set on the dirt floor of the cellar. The tops of the barrels were covered with sacks. The temperature of the cellar was kept below 40° F. with the relative humidity ranging between 80 and 90 per cent. The weight on November 30, after being transferred to the barrels, was 2,097 pounds. On April 3 they were again weighed at which time a loss of 23 pounds, or 1.1 per cent, was recorded. Since they were surrounded by a comparatively moist atmosphere the surface evaporation was reduced to a minimum, therefore the losses may be attributed largely to respiration.

PER CENT OF MARKETABLE TUBERS

In order to compare the different varieties under experiment with respect to the proportion of marketable tubers which they produce, the weights from all plats of each variety in the variety test were summarized and the percentages determined. The results are shown in Table 7.

TABLE 7

Per Cent of Marketable Tubers. Computed from Weights of Marketable Tubers and Total Weights after Sorting in Tables 1, 2, 3 and 4

Variety	Years of Test	Number of Plats	Marketable Tubers
			Per Cent.
Pearl	1915–1918	48	89 3
Peoples	1915	4	91.4
Rural New Yorker	1915–1918	38	95.7
Russet Rural	1916–1917	6	96.9
Green Mountain	1915	4	92.2
Charles Downing	1915–1917	10	84.7
Early Ohio	1915–1916	6	84.4
Late Ohio	1915–1917	8	84.2
Irish Cobbler	1915–1917	10	90.8
Peachblow	1915–1916	4	89.7
Russet Burbank	1915–1916	8	72.2
Garnet Chili	1915	2	91.8

This table shows very clearly the varietal differences in the percentage of marketable tubers produced. The varieties which lead in this respect are the Rural New Yorker and the Russet Rural. These are closely related varieties belonging to the same group. The lowest percentage was obtained from the Russet Burbank. This was probably due in part to the fact that the tubers are comparatively long and slender, so it is probable that many tubers went thru the screen endwise which would have gone over if they had been round tubers of the same weight. In commercial grading it is customary to use a 1¾-inch screen for this variety. Comparing the four varieties which are most extensively grown in the Greeley district we find that the two late varieties, the Rural New Yorker and Pearl, rank considerably higher than the two early varieties, the Charles Downing and Early Ohio, in the percentage of marketable tubers with the first named variety exceeding the Pearl by 6.4 per cent.

RUNNING OUT OF VARIETIES

This experiment was conducted in connection with the variety test to determine if possible whether the productivity of a variety can be maintained for a period of years without change of seed. This phase of the work was started in 1915 with seed from 10 sources, representing seven varieties. Seed was saved from the crop produced by each lot and grown the following year in comparison with new seed which came from the same source from which the 1915 seed was obtained. In 1917 the new seed was compared with stock from the same original source which had been grown at the station one and two years, respectively, while in 1918 comparisons were obtained between new seed and 1-, 2- and 3-year-old seed, all from the same original source. Because of the increase in the number of plats from year to year it was necessary to gradually reduce the number of varieties because of lack of space until in 1918 there remained only two varieties, the Pearl from Wisconsin and the Rural New Yorker from Colorado. The results are shown in Table 8.

In 1916 larger yields were obtained from the station seed in eight of the ten trials, the average increase in yield over that produced by the new seed being 13.3 bushels. In the two instances where new seed produced larger yields the seed came from Wisconsin. In 1917 in four out of five trials the largest yields were produced by the new seed. The yields from the two-year-old seed were in general slightly lower than those obtained from seed which had been grown at the station but one year.

In 1918, the number of sources from which new seed was obtained was reduced to two, the Pearl from Wisconsin and the Rural New Yorker from Colorado. In the case of the Pearl there was a gradual decrease in yield corresponding with the length of

TABLE 8

Yields of Crops Grown in 1916, 1917 and 1918 from New Seed and from Seed Grown at the Station for 1, 2 and 3 Years, Respectively. Summarized from Tables 1, 2, 3 and 4

VARIETY	Original source of seed	Yield per acre, field weights (bushels).									
		Crop of 1916 Year first grown at station			Crop of 1917 Year first grown at station			Crop of 1918 Year first grown at station			
		1916	1915	Difference	1917	1916	1915	1918	1917	1916	1915
Pearl	Colorado, irrigated	289.4	339.9	50.5	366.8	338.9	356.3	.....	.....	.....	.....
Pearl	Colorado, dry land	330.5	338.4	7.9	431.0	368.6	342.7	.....	.....	.....	.....
Pearl	Wisconsin	346.5	320.6	—25.9	415.5	343.6	339.1	327.7	316.5	294.5	272.8
Rural New Yorker	Colorado	293.8	324.3	30.5	369.9	394.6	391.9	261.8	319.1	324.4	301.0
Rural New Yorker	Wisconsin	332.2	289.4	—42.8	405.5	393.0	386.2	.....	.....	.....	.....
Charles Downing	Idaho	287.9	300.1	12.2	.....	.....	.....	.....	.....	.....	.....
Early Ohio	Minnesota	198.9	254.1	55.2	.....	.....	.....	.....	.....	.....	.....
Late Ohio	Colorado	293.8	312.0	18.2	.....	.....	.....	.....	.....	.....	.....
Irish Cobbler	Wisconsin	303.5	308.1	4.6	.....	.....	.....	.....	.....	.....	.....
Russet Burbank	Idaho	259.9	282.6	22.7	.....	.....	.....	.....	.....	.....	.....
Averages		293.6	307.0	13.3	397.7	367.7	363.2	.....	.....	.....	.....

time that the seed had been grown at the station. On the other hand the Rural New Yorker showed an increase in yield up to and including the third year and a decrease the fourth year, tho it should be noted that the yield of the 1915 seed was greater by 39.8 bushels per acre than that of the new seed. Whether the falling off in yield from the three-year-old seed indicates that a permanent degeneration has begun can be determined only by further experiments. The fact that the original stock from which this seed was obtained has been grown continuously in this locality without change of seed for approximately twenty years with no apparent signs of running out, suggests the improbability of any great deterioration in this variety so long as it can be kept free from certain diseases which tend to cause degeneration.

While the time covered by these experiments is not sufficient to settle the matter conclusively there are some deductions that can be made. One point of significance is the different behavior of the two varieties,. which is readily explained. The Rural New Yorker plats showed very little evidence of disease, in fact this variety appears to be very nearly immune to the diseases which are considered as being responsible for one form of degeneracy. On the other hand the Pearl variety, with the exception of the plats grown from the new seed, was badly affected with Mosaic disease which appeared to increase in intensity with the length of time that the seed stock had been grown at the station. Accompanying this condition was a gradual diminution of yield from year to year. A similar instance of running out due to a diseased condition of the plants was observed in the Peachblow grown in 1916 from one-year-old seed. It is believed that the greater part of the running out of varieties which has been observed by growers in the West is largely due to the effect of certain of the so-called nonparasitic diseases, including Mosaic, Leaf-roll and possibly others. These diseases attack the vines thereby reducing the vigor of the plants and ultimately the yield. The shape of the tubers is not necessarily affected so that the diseased condition may not be apparent in the cellar tho in the advanced stages rough, elongated types are frequently found.

There is another type of running out which is occasionally found in individual hills which appears to be more strictly a physiological degeneration. In this case the condition is usually one of excessive vine growth which is apparently not associated with any disease, a heavy production of seed balls and with tubers of abnormal shape with deep eyes. In the Greeley district this type has been observed most frequently in the Pearl variety. The abnormal tubers are usually pear-shaped with smooth, glossy skin which is generally tinged with pink, especially near the stem end. Experiments at the station have shown that the crop grown from these tubers is similar in character to that of the seed which was planted. So far it has been impossible to determine whether this condition was reached by successive stages or whether the transition from the normal type was sudden as in the case of mutations. While the pear-shaped type of tuber is characteristic of this form of degeneration it does not follow that all tubers of this type are run out, at least in certain varieties. For example, in 1918, tubers of this shape were selected from the Rural New Yorker and planted beside an equal number of tubers of the best type that could be found in the same lot of seed. The crop produced by the pear-shaped tubers was equally as good, both in regard to quantity and quality, as that produced by the good type of seed tubers.

Apparently in this case there was only a temporary modification of the individual tuber which was undoubtedly in some way effected by the nutrition of the plant during tuber formation and should not be considered a form of degeneration. These instances show that different varieties behave differently with respect to running out.

THE GREENING OF SEED

The variety used for this experiment was the Pearl. The seed was greened by spreading it out in a thin layer in trays and exposing it to strong light until the surface of the tubers had become thoroly greened. This required about two weeks. The spring greening was done in April and the fall greening the latter part of November. Short, thick sprouts were produced during the process of greening in the spring. Many of these were bruised or broken off in planting which was done with a machine. The yields and the increases or decreases resulting from greening are given in Table 9.

The results show that lower yields were produced by the seed which was greened in the fall than from that which had not been greened. It should be stated in this connection that the fall greening was very unsatisfactory. Because of the lack of strong light the greening at that time of the year was not as thoro as that which was done in spring; furthermore, there was some drying out and shrinking of the tubers due to the fact that it was necessary to keep the room in which they were stored during the greening process, heated to prevent freezing.

Aside from conclusions which may be drawn from experimental results, fall greening is believed to be impractical under the conditions which obtain in this locality. Practically all of the seed used by the growers is either picked out from the main crop during the winter at the time of sorting or is bought in the spring so that the seed is not available in the fall for greening at that time. The low night temperatures in the fall after the late varieties are dug would necessitate the transfer of the potatoes to the storage house each night or specially constructed buildings would need to be provided to prevent freezing and at the same time admit sufficient light for greening. The short daily period of sunlight of relatively low intensity at that time of the year would greatly prolong the period required for thoro greening.

The seed greened in spring produced a larger yield than the ungreened seed in each of the three years of the experiment. The increases in 1917 and 1918, however, were so small as to be scarcely significant from the practical standpoint tho they are very consistent. In 1916, when the effect of greening was most pronounced, the plants from the greened seed came up about two days earlier than those from the ungreened seed and produced a more vigorous growth of vines during the early stages of growth. This difference

TABLE 9

Comparison of Yields from Greened and Ungreened Seed.

TREATMENT OF SEED	Crop of 1916 (bushels)		Crop of 1917 (bushels)		Crop of 1918 (bushels)	
	Yield per acre	Increase or decrease (—)	Yield per acre	Increase or decrease (—)	Yield per acre	Increase or decrease (—)
Check—seed not greened	.....	....	426.0	....	.....	...
Seed greened in fall	.....	....	407.1	—6.1	.....	...
Check—seed not greened	337.9	....	400.3	....	352.5	...
Seed greened in spring	371.7	24.8	407.6	2.6	351.5	4.5
Check—seed not greened	355.8	....	409.6	....	341.4	...
Seed greened in fall	.....	....	403.3	—5.1	.....	...
Check—seed not greened	.....	....	407.1	....	.....	...
Seed greened in spring	382.8	31.2	417.5	3.9	342.9	2.1
Check—seed not greened	347.0	....	420.0	....	340.2	...
Average increase resulting from spring greening		28.0	.....	3.3	.....	3.3
Average decrease resulting from fall greening		....	.....	—5.6	.....	...

could be detected for about six weeks. In 1917 the germination appeared to be hastened slightly by greening tho the differences in the rate of growth disappeared after a few days. In 1918 the effects of greening observed in previous years could not be discerned except in the small increase in yield.

IRRIGATION

Considerable difference of opinion exists among practical growers regarding the stage of growth at which irrigation should be started. Some maintain that water should not be applied until after the tubers have set even tho the plants have begun to suffer from lack of water. Others hold that if the plants show need of water at an earlier period it should be applied.

To determine, if possible, which of these views is correct experiments were conducted in 1917 and 1918 with two of the late varieties, the Pearl and Rural New Yorker. Each plat consisted of eight rows. In 1917, when only the Pearl variety was used, one-half of each plat was planted with dry land seed and the other half with Wisconsin seed. In 1918 Pearl seed from Wisconsin and Rural New Yorker seed from Colorado were used for the respective halves of each plat. To overcome any effects which might arise from lateral movement of water in the soil the plats were separated by two discard rows the yields of which are not included in the experimental data.

The different periods at which irrigation was started were designated as ''checks,'' ''early,'' ''medium'' and ''late.'' On the check plats irrigation was started in 1917 just as the tubers were beginning to set. In 1918 tuber development was farther advanced at the time of the first irrigation which was delayed because of rains. The early irrigated plats received the first irrigation about two weeks before tuber formation had started. On the plats designated as ''medium,'' which were employed only in 1917, the first application of water was on the same date as that of the check plats. The total number of irrigations for the season was, however, one less. On the late irrigated plats irrigation was not started until after the tubers had made considerable growth. At that time the dark color and stunted appearance of the plants plainly indicated the need of water. These plats received the same number of irrigations as the ''medium'' plats but the first application was much later. The results are given in Table 10. In addition to the yields per acre based on actual weights the corrected yields have been

TABLE 10

Results Showing Relation of Yield to Time of Starting Irrigation.

Crop of 1917

Plan of Experiment	Dates of Irrigation			YIELD PER ACRE (BUSHELS)					
				Pearl, Dry Land Seed			Pearl, Wisconsin Seed		
	July	August	September	Actual Yields	Corrected Yields	Increase or Decrease (-)	Actual Yields	Corrected Yields	Increase or Decrease (-)
Check	21	14, 23, 30	7	462.8	.....	.....	454.8	.....	.....
Early	9, 27	14, 23, 30	7	476.7	480.1	17.3	458.8	463.5	8.7
Late	..	14, 23, 30	7	417.7	424.6	–38.2	409.6	419.1	–35.7
Check	21	14, 23, 30	7	452.5	.....	.....	440.6	.....	.....
Medium	21	14, 23	7	438.4	436.5	–16.0	425.5	428.4	–12.2
Early	9, 27	14, 23, 30	7	465.6	461.7	9.2	444.4	450.3	9.7
Check	21	14, 23, 30	7	458.3	.....	.....	431.8	.....	.....
Late	..	14, 23, 30	7	417.9	427.6	–30.7	388.7	393.7	–38.1
Medium	21	14, 23	7	438.6	457.9	– .4	413.2	423.1	– 8.7
Check	21	14, 23, 30	7	429.3	.....	.....	416.9	.....	.....

TABLE 10—Continued

Crop of 1918

Plan of Experiment	Dates of Irrigation			YIELD PER ACRE (BUSHELS)					
				Pearl			Rural New Yorker		
	July	August	September	Actual Yields	Corrected Yields	Increase or Decrease (-)	Actual Yields	Corrected Yields	Increase or Decrease (-)
Check	. .	11, 20, 29	......	387.5	.....	.....	325.7	.....	.....
Early	6	8, 20, 29	......	381.8	393.8	6.3	323.2	329.8	4.1
Late	. .	20, 29	......	314.1	338.1	-49.4	267.6	280.7	-45.0
Check	. .	11. 20, 29	......	351.5	.....	.....	306.0	.....	.....
Early	6	8, 20, 29	......	379.8	372.2	20.7	322.3	312.5	6.5
Late	. .	20, 29	......	328.4	313.3	-38.2	281.2	261.7	-44.3
Check	. .	11, 20, 29	......	374.2	.....	.....	335.3	.....	.....

SUMMARY

Average of the two series. Increase or decrease over checks. (Bushels per acre.)

	Crop of 1917		Crop of 1918	
	Pearl Dry Land Seed	Pearl Wisconsin Seed	Pearl	Rural New Yorker
Early	13.3	9.2	13.5	5.3
Medium	- 8.2	-10.5	....	....
Late	-34.5	-36.9	-43.8	-44.7

included. These corrections, which are for the purpose of eliminating so far as possible differences in yield due to variability in the soil, are calculated by adding to the yield of the plat next in succession after a given check plat one-third the difference between the yields of the check plats on either side if the yield of the second check plat is lower than that of the first. If the larger yield is produced by the second check plat, then one-third the difference is subtracted. Two-thirds of the difference is added to or subtracted from the yield of the plat next in order. Each group of four plats, consisting of two plats receiving different treatments and the two check plats on either side, is treated independently. The corrected yields are then compared with the yields of the preceding check plat.

In all cases the largest yields were obtained from the early irrigated plats. Compared with the check plats the omission of one irrigation on the ''medium'' plats resulted in significant decreases in yield. On the "late" plats large decreases followed the withholding of water until late in the season. Comparing the yields of the medium and late irrigated plats, which received the same number of irrigations, but beginning earlier, we find that the yields of the former are substantially larger.

In 1918 the proportion of the tubers which were marketable was determined for each of the lots grown under the different conditions of irrigation. The results are shown in Table 11.

It was found that in the case of both of the varieties used for this experiment the largest percentages of marketable tubers were obtained from the plats which had received the early irrigations. In the Pearl the check plats were next in order while in the Rural New Yorker the per cent of marketable tubers on the check plats was slightly lower than that which was obtained from the late irrigated plats tho the difference is small and possibly within the limits of error. It was observed during the process of digging that the

TABLE 11

Effect of Time of Starting Irrigation on Percentage of Marketable Tubers. Summary of the Two Series for 1918.

PLATS	VARIETY	
	Pearl	Rural New Yorker
	Per Cent	Per Cent
Early	93.2	95.2
Checks	91.7	93.1
Late	90.5	94.0

tubers of the Pearl variety appeared to be a little smoother and freer from knots on the early irrigated plats than on the others. No difference was found in the quality of tubers produced on the different plats of the Rural New Yorker. It is characteristic of this variety, however, to produce smooth tubers under practically all conditions.

While the evidence thus far obtained is wholly in favor of the early beginning of irrigation further experiments under a wide range of climatic conditions and with a greater number of varieties are necessary before the question can be definitely settled.

SIZE OF SEED

These experiments, which were started in 1915 for the purpose of determining the most economical size of seed to use, are part of the general project of the United States Department of Agriculture for the study of this problem. In addition to the work along this line in Colorado similar experiments have been conducted at Jerome, Idaho; Presque Isle, Maine, and Norfolk, Virginia.

EXPERIMENTS AT GREELEY, COLORADO

The sizes of seed used for these experiments included 1-, 2-, 3-, 4-, 5-, and 6-ounce seed pieces. Since the work was carried on with both whole and cut tubers the studies also include comparisons between these two kinds of seed. The separation of the seed tubers into different sizes was performed by first roughly grading them with a sorter, using screens of different sizes. The final division was then made by weight, placing each tuber on a spring balance graduated in grams, allowing a variation of 5 grams on either side of the exact ounce equivalent, except that in the case of 8- and 12-ounce tubers a variation of 10 grams in either direction was allowed. Where cut seed was used the tubers which were halved were cut lengthwise, while the quartered tubers were first cut lengthwise then at right angles to the long axis, the four pieces being of approximately the same weight. In 1915, 1916 and 1917 the planting was done by hand. In 1918 a planter was used. The distance between hills was 14 inches in 1915 and 1918, and 16 inches in 1916 and 1917. The rows, in all cases, were 36 inches apart.

The separation of the tubers into the two grades, marketable and culls, was based on weight in 1915, 1916 and 1917, those weighing three ounces or more (over 85 grams) being classed as marketable while those which weighed less than three ounces were considered as culls. In the experiment of 1918, which was on a field basis, the grading was done with a sorter having a 1⅞-inch screen. With the Rural New Yorker variety this size of screen separates the tubers at approximately the three-ounce size. No tubers less than ½ inch in diameter were included.

Since the results will be published in detail in the complete report of the size of seed experiments, only parts of the summarized data which bring out some of the most prominent features will be included in this report.

EXPERIMENTS OF 1915

Because of the small amount of seed available, the experiment of this season was on a comparatively small scale. The number of hills planted was as follows: One-ounce whole, 120 hills; three-ounce whole, 120 hills; three-ounce halved, 240 hills; four-ounce whole and halved, 60 hills each. The series was planted without duplication. The variety used was the Irish Cobbler. The calculated yields per acre are based on the hills present at the time of digging, no allowance being made for missing hills. The results, which are given in the 4th, 7th, 10th and 14th columns of Table 12, show that the number and weight of tubers per hill before sorting, which includes both marketable and culls, very consistently increased as the size of the seed piece increased. This was true for both the whole seed and the seed cut in halves. The marketable tubers and the calculated yields per acre also showed increases in the same direction with the exception of the six-ounce seed cut in halves which produced a slightly lower yield than the four-ounce halved. The difference, however, is so small as to be considered within the limits of error.

EXPERIMENTS OF 1916-1917

Since identical plans were followed in carrying out the experiments of these two years the results will be discussed together. The entire series was planted in duplicate each year with ninety hills of each lot in each series. The variety used in these experiments was the Rural New Yorker. Since the seed was planted by hand in an open furrow the soil dried out somewhat during the process of planting so that the soil which was directly in contact with the seed pieces did not contain as much moisture as is usually the case where the planting is done with a machine. Furthermore there was considerable drying out of the soil with which the tubers were covered during the hot, dry period which followed planting. These conditions made the test a severe one and undoubtedly served

TABLE 12

Relation of Size of Seed Piece to Number of Stems, Number and Weight of Tubers Per Hill, and Per Cent and Yield Per Acre of Marketable Tubers.

SIZE OF TUBERS	Weight of Seed Piece Planted Ounces	No. of Stems per Hill Greeley '16 &'17	Number of Tubers per Hill			Weight of Tubers per Hill (Ounces)			MARKETABLE TUBERS							
									Per Cent. of Weight				Bushels per Acre			
			Greeley 1915	Greeley '16 &'17	Greeley 1918	Greeley 1915	Greeley '16 &'17	Greeley 1918	Greeley 1915	Greeley '16 &'17	Greeley 1918	Carbondale '16	Greeley 1915	Greeley '16 &'17	Greeley 1918	Carbondale '16
1 Ounce Whole	1	1.8	4.4	4.3	3.2	17.9	25.1	23.5	80.3	93.4	95.5	....	186.7	229.1	295.7	.....
2 Ounce Whole	2	2.6	...	6.3	4.0	....	30.9	26.5	....	90.7	93.6	90.0	....	293.0	332.1	443.2
3 Ounce Whole	3	3.2	6.9	7.2	4.9	25.6	31.3	27.1	77.4	88.1	90.8	86.9	248.0	275.0	316.8	453.9
4 Ounce Whole	4	3.7	7.7	8.0	...	28.2	33.6	....	80.1	85.9	....	85.6	292.1	287.5	.....	460.9
5 Ounce Whole	5	4.5	...	9.2	...	....	34.8	....	....	83.7	....	86.6	.....	299.1	.....	462.7
6 Ounce Whole	6	5.0	9.2	10.1	...	31.5	36.3	....	76.2	83.4	....	....	311.1	319.0	.....	.....
2 Ounce Halved	1	1.8	...	4.0	3.1	....	23.6	23.7	....	93.2	96.1	....	.....	205.3	303.1	....
3 Ounce Halved	1½	2.3	5.1	4.8	...	20.2	27.0	....	82.1	92.0	....	88.1	205.7	235.1	.....	384.3
4 Ounce Halved	2	2.5	5.5	5.3	4.1	25.9	28.8	25.8	86.6	92.1	94.0	85.8	290.4	248.0	309.0	393.0
5 Ounce Halved	2½	2.6	...	5.6	...	....	27.7	....	....	90.4	....	85.0	.....	253.3	.....	380.3
6 Ounce Halved	3	3.1	6.7	6.3	5.0	26.7	28.5	27.1	82.2	89.7	90.5	86.0	285.2	260.3	295.7	418.1
3 Ounce Quartered	¾	1.5	...	3.4	...	....	23.4	....	....	94.6	....	....	.....	187.7	.....	.....
4 Ounce Quartered	1	1.6	...	3.6	3.2	....	23.7	23.6	....	95.0	95.1	....	.....	192.9	286.3	.....
5 Ounce Quartered	1¼	1.9	...	3.9	...	....	25.6	....	....	94.1	....	....	.....	188.4	.....	.....
6 Ounce Quartered	1½	2.0	...	4.1	...	....	26.0	....	....	93.7	....	88.8	.....	199.8	.....	378.5
8 Ounce Quartered	2	...	...	...	3.8	....	....	24.3	.....	....	93.1	89.7	.....	.....	291.8	402.2
12 Ounce Quartered	3	...	...	...	4.5	....	....	24.5	....	....	90.9	....	.....	.....	288.8	.....

to accentuate the value of the larger seed to a greater degree than is shown in the experiments where the planting was done with a machine. In each of the two years there were a few hills which were badly diseased as the result of attacks of Rhizoctonia and Fusarium. These hills, which were abnormally small, were dug separately and discarded. The yields per acre were calculated on the basis of the total area planted.

Since the amount of seed required to plant a given area varies in proportion to the size of the seed piece planted it follows that the larger the seed used the greater will be the cost per acre, which must be taken into account in determining the economy of the use of the different sizes of seed. To offset this increased seed requirement for the larger sizes the amount of seed used for each size was subtracted from the calculated yield, giving what is termed the net yield. The results are shown in the 3rd, 5th, 8th, 11th and 15th columns of Table 12. Within each of the three groups the number of stems, the number of tubers and the weight of tubers per hill increased as the size of the seed piece increased. Considering only the marketable tubers we find the same general trend in the case of the number and weight and the net yield per acre though a few exceptions are noted. The most significant point in connection with the net yields is the well defined decrease where seed pieces weighing less than two ounces were used. Above that size the differences are either very small or inconsistent. The per cent of marketable tubers, as regards both number and weight, varies inversely as the size of the seed piece, the more uniform gradation being found in the yields obtained from the whole seed.

In Table 13, which is summarized from Table 12, are shown comparisons where seed pieces of the same weight are taken from tubers of different weights. In each of the first three groups, where whole seed is compared with cut seed pieces of equal weight, the whole seed produced a greater number and weight of tubers, including both the total and marketable, and a larger net yield after deducting the weight of the seed used. A comparison of the results obtained from the halved and quartered seed, which appears in the first and last groups, indicates the superiority of the seed cut in halves over that which is cut in quarters.

EXPERIMENTS OF 1918

This experiment was conducted under practical field conditions with the planting and digging done by machinery instead of by hand as in former years. The same variety, the Rural New Yorker,

TABLE 13

Comparisons of Results Obtained from Whole, Halved and Quartered Seed Where Seed Pieces of the Same Weight were Used.

SIZE OF TUBERS	Weight of Seed Piece Planted Oz.	No. of St'ms per Hill.	No. of Tubers per Hill		Wt. of Tubers per Hill (Oz.)		MARKETABLE TUBERS						NET YIELD MARKETABLE TUBERS PER ACRE		
							Per Cent of Weight			Bushels per Acre					
		Greeley '16–17'	Greeley '16–'17	Greeley 1918	Greeley '16–'17	Greeley 1918	Greeley '16–17'	Greeley 1918	Carbondale '16	Greeley '16–'17	Greeley 1918	Carbondale '16	Greeley '16–'17	Greeley 1918	Carbondale '16
1 Ounce Whole	1	1.8	4.3	3.2	25.1	23.5	93.4	95.5	....	229.1	295.7	.....	217.8	282.7	.....
2 Ounce Halved	1	1.8	4.0	3.1	23.6	23.7	93.2	96.1	....	205.2	303.1	.....	193.9	290.1	.....
4 Ounce Quartered	1	1.6	3.6	3.2	23.7	23.6	95.0	95.1	....	192.9	286.3	.....	181.6	273.3	.....
2 Ounce Whole	2	2.6	6.3	4.0	30.9	26.5	90.7	93.6	90.0	292.9	332.1	443.2	270.2	306.1	420.9
4 Ounce Halved	2	2.5	5.3	4.1	28.8	25.8	92.1	94.0	85.8	248.0	309.0	393.0	225.3	283.0	370.7
8 Ounce Quartered	2	...	...	3.8	....	24.3	....	93.1	89.7	.....	291.8	402.2	.....	265.8	379 9
3 Ounce Whole	3	3.2	7.2	4.9	31 3	27.1	88.1	90.8	86.9	275.0	316.8	453.9	241.0	277.8	420.3
6 Ounce Halved	3	3.1	6.3	5.0	28.5	27.1	89.7	90.5	86.0	260.3	295.7	418.1	226.3	256.7	384.5
12 Ounce Quartered	3	...	...	4.5	....	24.5	....	90.9	....	.....	288.8	.....	.....	249.8	.....
3 Ounce Halved	1½	2.3	4.8	...	27.0	....	92.0	....	88.1	235.1	.....	384.3	218.1	.....	367.5
6 Ounce Quartered	1½	2.0	4.1	...	26.0	....	93.7	....	88.8	199.8	.....	378.5	182.8	.....	361.7

was used this year as in 1916 and 1917. The seed was limited to one-, two- and three-ounce sizes which included whole seed and seed cut in halves and quarters so that three sets of comparisons were obtained with each of the three kinds and sizes of seed. It has been found by previous experience that the planter would not, without modification, successfully plant sizes larger than three ounces, in fact, three-ounce seed, especially that which was cut in halves, gave some trouble. One row, 246 feet long, of each size and kind of seed was planted and the series was duplicated. Soil and moisture conditions were ideal at the time of planting which are considered largely responsible for the nearly perfect stand that was secured. The crop was practically free from disease. The results are shown in the 6th, 9th, 12th and 16th columns of Table 12.

In each of the three groups shown in Table 12 the number and weight of tubers per hill increased directly with the increase in the size of the seed piece. The percentage of the weight of tubers which were marketable varied inversely with the size of the seed piece. In comparing the calculated yields per acre the two-ounce seed appears to have produced slightly better results than either of the other two sizes though in the two groups where cut seed

Fig. 5—Residence and laboratory at experiment station.

was used the differences are so small as to suggest that they are within the limits of error.

The comparisons of whole, halved, and quartered seed where seed pieces of the same size were used, show that the kind of seed had practically no influence on the number and weight of the tubers produced in the one-ounce group. In the two- and three-ounce groups there was a decided falling off in tuber production per hill where quartered seed was used. Within each group there was little difference in the per cent of marketable tubers. The yields of marketable tubers per acre, also the net yields after deducting the weight of the seed used, were, in all cases except one, largest where whole seed was used, with the yields from halved seed next in order. In the one-ounce group the slightly lower yield where the whole seed was used is believed to be due to so-called experimental error, which is indicated by the abnormally low yield produced by the one-ounce whole seed in the first series of this experiment. In the second series the yield from the corresponding plot was in line with those of the other groups.

COOPERATIVE EXPERIMENTS AT CARBONDALE, COLORADO

In 1916, in addition to the work which was carried on at the station with the different sizes of seed, an experiment was conducted on a field basis at Carbondale on the ranch of the Crystal River Land Company, commonly known as the Sweet Ranch. The relatively cool summers at this place resulting from the high altitude, which exceeds 6,000 feet, coupled with the deep fertile soil of a fine sandy loam type make conditions especially favorable for potato production. At the time of planting, the soil was in excellent condition and the supply of moisture abundant. This favorable environment undoubtedly reduced to a minimum the differences in value of the different kinds and sizes of seed so far as germination was concerned. Two varieties were planted, the Russet Burbank and Peachblow. Two lots of seed were used for each variety, one grown on a special seed plot, the other taken from the ordinary market stock, both of which were grown on the ranch. Each plot consisted of one row 600 feet long. The rows were 39 inches apart and the distance between hills was 15 inches. The series was not duplicated. The crop was planted May 19 to 22 and dug October 23 and 24. Some difficulty was experienced in planting the larger sizes, particularly the five-ounce Russet Burbank seed. This may explain in part the falling off in the yield of this seed. Unfortunately this point cannot be checked up by the stand since no counts were made of the number of plants in each row. The separation into marketable and culls was made with a sorter using a 1⅞-inch screen for the Russet Burbank and a 2-inch screen for the Peachblow. The sorting was done February 7 and 8. The averages of the yields from the four sources of seed are shown in the 13th and 17th columns of Table 12 and the 10th, 13th and 16th columns of Table 13.

While the results are somewhat conflicting, considered as a whole, the general tendency is toward an increase in yield of marketable tubers corresponding with the increase in size of the seed piece planted. After deducting the amount of seed used the net yields from the smaller sizes are slightly larger in the case of the whole seed though the differences are small, while with the cut seed there is in general an increase with the larger sizes. Comparing whole and cut seed where seed pieces of the same weight were used we find a significant increase in favor of the whole seed. The two comparisons of seed cut in halves and in quarters show a smaller yield from the seed cut in halves in the case of the two-ounce seed pieces and a larger yield where the 1½-ounce seed pieces were used. The differences, however, are so small as to have little significance.

GENERAL SUMMARY OF SIZES OF SEED

Considering the results of all the size of seed experiments as a whole, we find the superiority of whole seed clearly shown. This form of seed has consistently produced a better stand, a larger total yield and generally a larger yield of marketable tubers than cut seed. Whole seed was also found to produce a greater number of tubers per hill which, however, were in most cases of smaller average size than those grown from cut seed. This feature may be utilized to advantage in controlling to a certain extent the character of the crop. For example, the Rural New Yorker normally sets a small number of tubers, some of which usually develop into oversized stock. The use of whole seed, which would tend to increase the number and decrease the size of the tubers, would undoubtedly result in a crop of greater uniformity and better quality than that grown from cut seed. On the other hand, the Charles Downing, a variety in which the percentage of small tubers is so large as to be considered an undesirable characteristic, would, it is believed, produce more profitable crops if cut seed were used, provided as good a stand were secured from this kind of seed as from whole seed.

A study of the influence of the size of seed piece on the yield shows some inconsistencies, which may be attributed chiefly to the effect of the different conditions under which the crop was grown during the course of the experiment. There appears to be a direct relation between the size of the seed piece and the yield where the seed was subjected to unfavorable conditions during the period of germination, as was the case in 1916 and 1917. On the other hand, where conditions were favorable during this period, this relationship is not so apparent; in fact, after deducting from the marketable tubers the amount of seed used, the larger sizes of seed were found to be less economical. It is, however, essential in all cases to use a seed piece of sufficient size to furnish the necessary amount of food material to give the young plants a good start and especially to insure against loss of stand due to unfavorable conditions during germination which cannot be foreseen at the time of planting. The experimental results indicate that while the most economical size of seed to use may vary according to conditions, it should at least equal or exceed two ounces in weight.

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Bulletin 262 October, 1920

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

SOD DISEASE OF CHICKENS

(Vesicular Dermatitis)

By

I. E. NEWSOM and W. H. FELDMAN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1920

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SOD DISEASE OF CHICKENS

(Vesicular Dermatitis.)*

Synonyms—Foot and Head Disease—Foot and Head Blister

History—For the past 7 or 8 years letters coming in from eastern Colorado during May, June and July have described a peculiar disease affecting the feet and heads of chickens, which descriptions did not conform to the symptoms exhibited by any previously known malady. It was frequently mentioned that the toes became scabby and that the chickens became blind.

Finally about six years ago several of these affected birds were sent to us for examination. On account of the condition of the feet, we suspected that they had been walking in some caustic material such as lye or lime, but further information gave no clew to any such experience. We were informed by those writing that in many cases information had been sought through poultry journals and from other experiment stations, but in no case had any one, to whom application had been made, been able to satisfactorily recognize the malady.

Owing to the continuance of the letters and the apparent seriousness of the disease, we began some three years ago to make a systematic investigation with a view to setting down the more important facts, and if possible, to determine the cause.

As a result of these investigations, we believe the disease to have existed in eastern Colorado for at least twenty years. We have the statement of Mr. Gus Setterburg of Elba, Colorado, that he has observed the disease practically every year for the past thirteen years. Many who live in this district tell us that several years ago their chickens had the disease but that in recent years they have had no difficulty with it. It appears to be most prevalent during the months of May, June and July and is largely a disease of small chickens during the first month of life, but does in some cases affect old hens as well.

So far as our observations go the disease is quite prevalent throughout all of Colorado east of the Rocky Mountains wherever prairie sod remains unbroken. We have never had a report of it from the Western Slope of this state. The disease appears also to be fairly well known in western Kansas, Nebraska and in eastern Wyoming. In no instance have we seen the disease on irrigated land but it does occur in irrigated districts in places where the chickens have the run of sod above the irrigating ditch.

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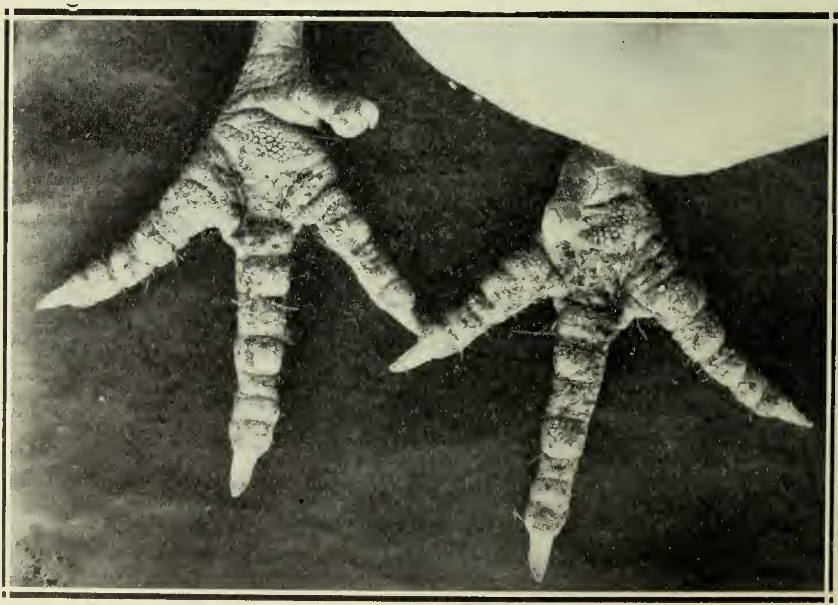
* Since this disease has never been previously described in any literature to which we have access, we find it necessary to select a name for it. There is no name in common use even among those who suffer from its effects. We have been wont to speak of it as foot and head disease but since our observations seem to indicate that it is also associated with virgin sod, we have selected the name which appears at the head of the pamphlet. The term "Vesicular Dermatitis" is used technically because of the inflammatory condition of the skin of the face and feet, which is so frequently associated with the formation of blisters.

It has been so serious in certain localities as to cause settlers to stop raising chickens entirely. In several instances it has been known to cause from 50 to 90 per cent of fatalities in all young chickens raised in a single season, and several of the homesteaders have explained to us that they were unable to raise chickens with any degree of satisfaction on account of this one disease. In other places, it seems to take only a small percentage and while it causes some loss, yet it is not looked upon as being serious. It has also been the experience of some that the disease was extremely virulent in certain years, only to disappear entirely in the year succeeding. We could find no association with either dry or wet years.

Cause—As is usually the case with an unknown malady, various explanations have been given as to its cause. While the problem appeared to be capable of easy solution during the earlier part of our investigation, we now find that we have not been able to accurately determine the cause of the trouble. Among the causes most commonly suggested may be mentioned chemicals, sand, sun, ants, cactus, sod and infection. The presence of caustic chemical substances has never been shown to exist, and as a consequence this theory had to be abandoned. Sand is quite prevalent throughout

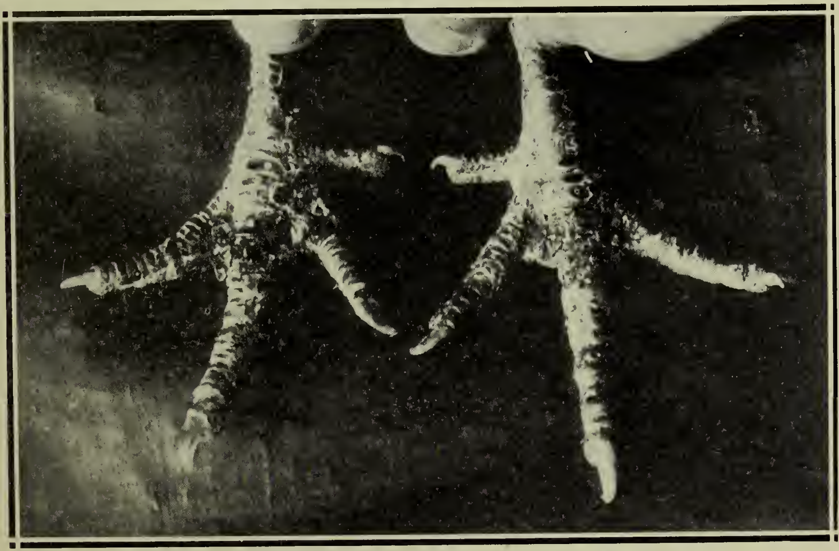


Showing spines in the feet after running on cactus for one day.

the district affected but the disease appears on adobe as well as on sandy soil. Furthermore, sandy soil is also present in irrigated districts. Throughout this whole area the sun is extremely hot in summer and it is well known that white hogs do not thrive well because of the fact that the sun blisters the skin. This theory has been given much credence by some, but does not seem in itself to be a sufficient explanation since, in experiments conducted by us, the chickens kept on plowed ground in the sun did not develop the disease.

Ants are of course very prevalent throughout the district but the evidence for this theory is not conclusive. The presence of cactus throughout all of this district and their practical absence in plowed ground, early led to the assumption that the spines of this plant were responsible for the difficulty. However, in our experiments, chickens on cactus alone did not develop the trouble.

The evidence in favor of the disease being associated in some way with sod is considerable. In the first place, the disease has never been known on irrigated land, nor does it occur on dry land where the sod has been broken up and the fields have been cultivated for a few years. We have in our records the outline of one case in which a lady lived on an irrigated farm near Fort Collins for several years, having no trouble, and in fact being in entire ignorance that there was such a disease. During 1916, she moved to a dry hill above the ditch, not, however, a half mile distant from her former location. There, during the first summer, the disease manifested itself and caused a considerable loss. The following year she had the same

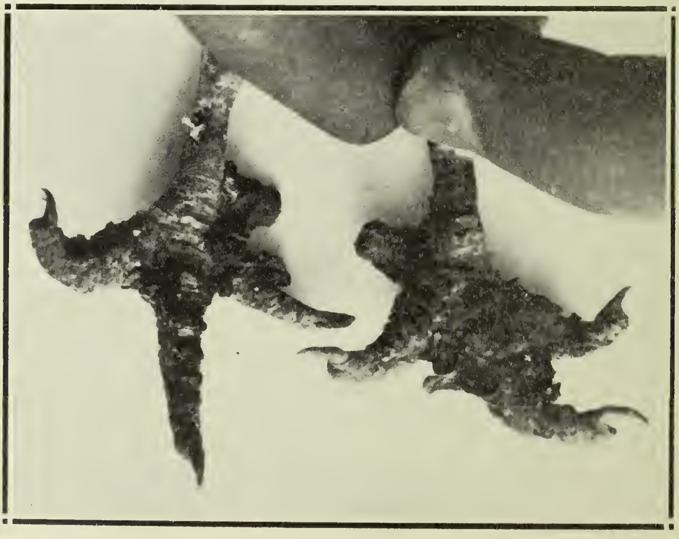


Scabs are falling off and the chicken is making a fair recovery.

experience. The year after that she moved away and during 1918 a new tenant took the place. A considerable amount of the ground in the immediate vicinity of the house was plowed with the result that only a few chickens were affected. Since that time there has been no trouble on that place.

In another instance the house was located not 50 feet above an irrigating ditch and on many days the chickens, of course, ran down across the ditch. The disease developed in one brood, with the loss of all but two chickens, including the old hen. Mrs. George William Day of Orchard, Colorado, informed us in 1918 that she had lived on the place occupied at that time for six years and that she had the disease every year but one, that one being a year when she had raised the chickens entirely under cover and consequently both in the shade and off the sod. Experiments seem to point conclusively to the association of the disease with sod.

It seemed to us that there was a strong probability that the disease was infectious, if not contagious, and as a consequence we attempted several times to isolate an organism which might have some association with the malady, but always with negative results. We did in one case isolate two separate organisms, one a coccus and another a bacillus, but neither would produce the disease on inoculation. In most all of our cases the cultures remained sterile when made from the material within the vesicles. In several instances, we removed the vesicular content with a sterile hypodermic syringe and inoculated it under the skin of the feet of healthy chickens, with negative results. In at least three different instances, we placed

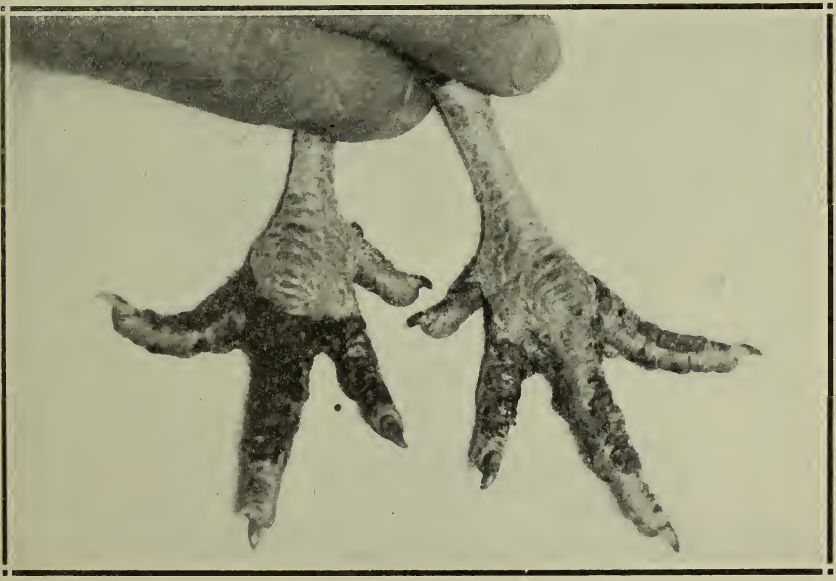


The scabs have piled up and the ends of two of the toes have dropped off, making walking very difficult.

healthy chickens in cages with affected chickens, but in no case were we able to show any transference of the disease. Consequently, while we still lean to the infection theory, we must admit that our experiments have not added any support to it.

Our investigations are now outlined with the possibility in mind that an infection does exist and that it gains entrance through abrasions caused by cacti or Russian thistles. For this view, however, we have no positive evidence.

Symptoms—The disease frequently manifests itself during the first week of life, its presence being evident to the observer because of the fact that the affected chicken becomes dull and remains behind the rest of the brood. A close examination at this time will often reveal the presence of blisters between the toes or possibly small scabs on top of the toes and on the lower portion of the leg. Scabs have not been found on the under surface of the toe. The whole foot is usually swollen and is very tender to the touch. Owing to the pain, the chicken sits down a great deal. In the course of two or three days the vesicle ruptures and is replaced by a thick heavy scab. The toes increase in size and become very rigid. Occasionally a joint or even a whole toe drops off. If the chicken survives, the scabs disappear in the course of two or three weeks longer and the toes become extremely distorted, turning usually in an upward direction so that the only portion of the foot that touches the ground is the heel. During the scabby stage, chickens pick at the feet a great deal.



Showing a moderately bad case in the later stages.

The symptoms may or may not appear on the head, and in some instances they may show on the head and not on the feet. In the early stages small vesicles may be found in the unfeathered skin around the bill and around the eyes. These are followed by considerable swelling, increasing redness and later by the presence of scabs. Often the eyelids become glued together and the chicken becomes totally blind. It appears that many chickens starve in this stage because of inability to find food. Older chickens are not nearly so frequently affected, but when the disease does attack them, it produces similar conditions of the feet and shows considerable swelling around the eyes with rather extreme redness. Vesicles have not been noted in hens, it requiring from one to two weeks in most instances for the disease to prove fatal; whereas in small chickens, the disease may terminate fatally in one or two days.

The flock mortality may run as high as 90 per cent in virulent outbreaks. Generally, however, it will not average above 20 per cent. Most of the affected birds die and the rest are practically worthless, since they become stunted and their feet are so distorted that they can not get around readily. As a consequence they are frequently destroyed, even though they appear to recover from the acute symptoms of the disease. Therefore, it may safely be said that of the chickens which are affected, the loss is practically 100 per cent.

Differential Diagnosis—The disease is more apt to be mistaken for roup than any other malady, but can be rather easily differentiated since roup is largely a cold weather disease and this appears in the summer. Furthermore, the disease under consideration affects

Showing typical posture in bad cases. Walking causes such pain that the chicken sits a great deal.

nore especially small chickens, whereas roup appearing in the winter ime is more likely to be a disease of adults. The swelling associated vith roup is more frequently due to accumulation within the maxilary sinus, whereas the inflammatory disturbance in this disease eems to be confined to the skin. The sod disease does not show the resence of false membranes in the mouth as does roup. Contagious pithelioma can be differentiated because of the warty projections ssociated with it, whereas in the sod disease the comb and wattles nay become scabby but not warty. Bumble foot might be confused ut is usually an inflammatory condition of the deeper structures nd is seldom associated with the presence of scabs on the upper urface of the toes. Scaly leg can be differentiated by finding the nites and also by the fact that it is largely a disease of the leg rather han of the toe.

Treatment—The most common treatment which has been used onsists in dipping the affected members in kerosene oil. Furthernore, this treatment seems to have been more effective than others vhich are more complicated. The daily dipping of the feet and bills n kerosene oil has in many instances been followed by rather rapid nd fairly permanent improvement. This is especially valuable for lder chickens where the disease is more chronic. No treatment eems to be of much avail in very young birds. Others recommend lipping in one of the coal tar preparations which are commonly sed for dipping sheep and cattle, following this by the use of aseline, lard or zinc ointment. While these treatments will be ound helpful, they should in no case be depended upon for permaent results.

Prevention—As the prairies are coming under cultivation, the lisease appears to be growing less prevalent and will doubtless in ime completely disappear. In the meantime its exit can be hastened y plowing up the sod in the immediate vicinity of the chicken ouse and planting to some crop. If chickens could be confined on lowed ground, it seems reasonable to believe that the disease would ot develop. Irrigation seems also to successfuly eradicate the nalady.

Acknowledgment—Our thanks are due to Drs. H. S. Eakins and . W. Alkire, members of the station staff during a portion of the ime the work was in progress and to Mr. and Mrs. Gus Setterburg, Ir. and Mrs. Elmore Chipps and Mr. and Mrs. Geo. Wm. Day who urnished material and gave much assistance in the investigation.

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202.—**Testing and Handling of Milk and Cream,** by Roud McCann. 32 pages.

Deals with herd testing, milk testing, care of milk and cream, care and sampling of cream, cream stations, and dairy law.

203.—**Costs on the Colorado Agricultural College Farm,** by Alvin Kezer, 56 pages.

A plot of the college farm is given with costs of production of various farm crops, methods of determining their yield per acre. The method of employing the college farm department as a college and experiment station service bureau, is also explained.

205.—**Yellow-berry in Wheat,** by Wm. P. Headden. 38 pages.

The bulletin discusses reasons heretofore given for the production of yellow-berry and gives the results of experiments that seem to prove that the chief cause is the excess ratio of potash salts to the nitrates in the soil. One colored plate.

209.—**Irrigated Agriculture in the San Luis Valley,** by V. M. Cone and Alvin Kezer. 32 pages.

This bulletin gives the results of field investigations and the growing of crops in the San Luis Valley for three consecutive years. It deals with such topics as topography, climate, soil, irrigation, crop rotation and the growing of such crops as alfalfa, peas and the common grains.

217.—**A Study of Colorado Wheat, Part II,** by Wm. P. Headden. 48 pages.

This bulletin is a continuation of the work reported by Dr. Headden in Bulletin 208. It contains a very large number of chemical analyses and is of chief interest to technical workers. There are practical conclusions concerning the effect of soil, climate, moisture, and cultivation on the quality of the crop produced.

218.—**A Bacterial Stem Blight of Field and Garden Peas,** by W. G. Sackett. 44 pages.

Ths is a technical bulletin which describes a bacterial stem blight of field and garden peas. It contains an account of the history, distribution and symptoms of the disease, together with a complete description of the causal micro-organism. Methods of infection, control measures and variety tests for resistance are also considered.

219.—**A Study of Colorado Wheat, Part III,** by Wm. P. Headden. 132 pages.

Continuation of Bulletin 217, giving many pages of analyses of wheat.

223.—**A Fruit Survey of Mesa County,** by E. P. Sandsten, R. A. McGinty and T. F. Limbocker. 52 pages.

A complete orchard survey of Mesa County, Colorado, giving varieties, acreage, bearing and non-bearing trees.

224.—Native Vegetation and Climate of Colorado In Their Relation to Agriculture, by W. W. Robbins. 56 pages.

A study of the native plants in the mountainous sections of Colorado as indicators of crop possibilities.

228.—Divisors, by V. M. Cone. 52 pages.

Tables for the computation of water through divisions of different dimensions.

229.—Brisket Disease (Technical), by I. E. Newsom. 32 pages.

Gives a rather full account of the history and cause of this disease and the remedy.

231.—Black Alkali in the San Luis Valley, by Wm. P. Headden. 15 pages.

A discussion of the condition of the valley from the standpoint of its alkalis.

233.—Grasshopper Control, by Charles R. Jones. 27 pages.

Gives habits of common grasshoppers with full directions for methods of control.

234.—Beans in Colorado and Their Diseases, by Alvin Kezer and W. G. Sackett. 32 pages.

This bulletin gives information concerning varieties, soils, planting, culture, irrigation, harvesting, machinery, marketing, cost of production and bean diseases.

235.—Reclaiming Nitre Soil in Grand Valley, by E. P. Sandsten. 8 pages.

Records the result of experiments for the purpose of reclaiming soils that had gone bad from the presence of niter, "black alkali."

236.—The Dandelion in Colorado, by B. O. Longyear. 36 pages.

A well illustrated bulletin giving the life history of the dandelion and the results obtained in using different means of control.

237.—Is Colorado Wheat Soft? by Wm. P. Headden. 32 pages.

Gives the results of experiments showing the causes leading to the production of "yellow-berry" or "soft wheat."

238.—Cleaned, Treated and Tested Seed for Colorado, by W. W. Robbins, H. E. Vasey and G. E. Egginton. 40 pages.

Gives information concerning selecting, storing, testing, planting, cleaning and otherwise dealing with seeds. Also a full explanation of the Colorado Seed Law.

239.—Alkali in Colorado, Including Nitrates, by Wm. P. Headden. 76 pages.

A popular discussion of the common alkalis occurring in Colorado soils, with recommendations as to methods of control.

240.—Irrigation by Means of Underground Porous Pipe, by E. B. House. 12 pages.

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Treats of soil, seed planting, cultivation, irrigation, grading, diseases, storage, etc.

244.—A Study of Colorado Wheat, Part IV, by Wm. P. Headden.

Treats of effect of food supply, irrigation, nitrates, hardness, fallowing, bread making quality, milling, etc.

245.—Colorado Climatology, by Robert E. Trimble.

Gives weather data compiled by Colorado Experiment Station from 1887-1917, with comments.

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246.—**A New Poisonous Plant, The Whorled Milkweed (Asclepias verticillata),** by George H. Glover, I. E. Newsom and W. W. Robbins.

A well illustrated bulletin giving valuable information concerning this very poisonous plant and the loss it causes to livestock in Colorado.

247.—**A Study of Colorado Wheat, A Resume of Bulletins Nos. 205, 208, 217, 219, 237 and 244,** by Wm. P. Headden.

A summary of results reached in studies of this subject, most of which have been reported in Parts I to IV.

248.—**Alfalfa Dodder in Colorado,** by W. W. Robbins and G. E. Egginton,

Habits of dodder, occurrences in the state and means of control.

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A well illustrated, technical bulletin, giving results of a large amount of original research along the line indicated in the title.

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251.—**The Identification and Control of Colorado Weeds,** by W. W. Robbins and Breeze Boyack.

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256.—**Horticulture at High Altitudes;** gives results of experiments in this line in Colorado. By R. A. McGinty.

257.—**Factors that Affect Alfalfa Seed Yields,** by P. K. Blinn.

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92. Large potato vines and no potatoes. Wendell Paddock. 1904.
93. Colorado hays and fodders. Alfalfa, timothy, native hay, corn fodder, sorghum, salt bush. Digestion experiments. William P. Headden. 1904.
94. Report of the entomologist. I. Some of the more important insects of 1903 and an annotated list of Colorado *Orthoptera*. C. P. Gillette. II. Some new Colorado *Orthoptera*. Lawrence Bruner. III. Bees of the genus *Nomada* found in Colorado. T. D. A. Cockerell. 1904.
95. Early cantaloupes. P. K. Blinn. 1904.
96. Shade trees of Denver. W. Paddock and B. O. Longyear. 1905.
97. Feeding steers on sugar beet pulp, alfalfa hay, and farm grains. W. L. Carlyle, C. J. Griffith and A. J. Meyer. 1905.
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99. How can we maintain the fertility of our soils? W. P. Headden. 1905.
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PRESS BULLETINS.

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Rainfall on the plains. L. C. Carpenter. In bulletin 123:21, 1907.

REPORTS.

First annual report. C. L. Ingersoll. 1888.

Second annual report. C. L. Ingersoll. 1889.

Third annual report. C. L. Ingersoll. 1890.

Fourth annual report. Walter J. Quick. 1891.

Fifth annual report. Walter J. Quick. 1892.

Sixth annual report. Alston Ellis. 1893.

Seventh annual report. Alston Ellis. 1894.

Eighth annual report. Alston Ellis. 1895.

Ninth annual report. Alston Ellis. 1896.

Tenth annual report. Alston Ellis. 1897.

Eleventh annual report. Alston Ellis. 1898.

Twelfth annual report. L. G. Carpenter. 1899.

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Fourteenth annual report. L. G. Carpenter. 1901.

Fifteenth annual report. L. G. Carpenter. 1902.

Sixteenth annual report. L. G. Carpenter. 1903.

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Eighteenth annual report. L. G. Carpenter. 1905.

Nineteenth annual report. L. G. Carpenter. 1906.

Twentieth annual report. L. G. Carpenter. 1907.

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Twenty-ninth annual report. C. P. Gillette. 1916.

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Thirty-first annual report. C. P. Gillette. 1918.

SPECIAL RIVER BULLETIN.

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1901. Nos. 1-21. Gives flow of the Cache a la Poudre river for May 27-Oct. 15, 1901.

1902. Nos. 1-20. Gives flow of the Cache a la Poudre river for June 10-Oct. 21, 1902.

ABBREVIATIONS

B., bulletin; P. B., press bulletin; R., report; Spec. B., special bulletin.

EXPLANATIONS

Bulletin No. 64 contains press bulletins 1-11 inclusive. Bulletin No. 123 contains press bulletins 18, 33-39 inclusive, 46, and three press bulletins not numbered.

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    compared with red clover and pea-vine. B. 35 :33, 1896.
    losses. B. 57 :10, 1900.
  experimental studies. B. 128 :3, 1908; B. 154, 1910; B. 181, 1911.
  fertilizer experiments. B. 57 :11. 1900.
  flowers, analysis. B. 35 :28, 1896.
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  fungous diseases of. B. 212 :9, 1915.
  furfurol in. B. 124 :16, 1907.
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    compared with timothy hay. B. 124 :36, 1907.
    cut hay vs. whole hay. B. 151 :3, 1910; B. 187, 1913.
    self feeders. B. 151 :6, 1910; B. 187 :10, 1913.
    with sugar beet pulp and corn. B. 102 :3, 1905.
    with sugar beet pulp and grains. B. 97, 1905.
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  irrigation. B. 8 :6, 1889.
  leaves—
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  moisture's effect on. B. 110 :7, 1906.

- Alfalfa (continued)—
  - nitrogen free extract. B. 111 :5, 1906.
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  - parasites of. B. 8 :6, 1889.
  - pasture for sheep. B. 52 :3, 1899.
  - pentosans in. B. 124 :16, 1907.
  - proteids removed from. B. 124 :19, 1907.
  - roots—
    - analysis. B. 35 :56, 1896.
    - description. B. 35 :44, 1896 ; B. 110 :15, 1906 ; B. 111 :9, 1906.
    - fertilizing value of. B. 35 :60, 1896 ; B. 111 :10, 1906.
  - seed—
    - amount for sowing per acre. B. 35 :37, 1896.
    - cleaning. B. 248 :11, 1918.
    - experiments. B. 110 :10, 1906 ; B. 191:6, 1913.
    - factors influencing production. B. 191 :3, 1913.
    - germination. B. 35 :41, 1896 ; B. 110 :11, 1906 ; B. 111 :8, 1906.
    - improvement experiments. B. 121 :3, 1907.
    - irrigation. B. 191 :7, 1913.
    - selection studies. B. 154, 1910.
    - shipped into Colo. B. 153 :14, 1910.
  - soil analysis for. B. 35 :65, 1896 ; B. 111 :11, 1906.
  - stem blight *(Pseudomonas medicagnis)*—
    - cause. B. 158 :6, 1910 ; B. 159 :6, 1910.
    - description. B. 158 :4, 1910 ; B. 159 :4, 1910.
    - field experiments. B. 158 :28, 1910 ; B. 159 ; 11, 1910.
    - greenhouse experiments. B. 158 :24, 1910 ; B. 159 :10, 1910.
    - history. B. 159 :3, 1910.
    - method of infection. B. 158 :9, 1910 ; B. 159 :7, 1910.
  - stem blight—
    - organisms, description. B. 158 : 11, 1910.
    - treatment. B. 158 :31, 1910 ; B. 159 :14, 1910.
  - stems, analysis. B. 35 :26. 1896 ; B. 110 :8, 1906.
  - varieties. B. 111 :4, 1906 ; B. 128 :4, 1908.
    - hardiness test. B. 181. 1911.
- Alfalfa. W. P. Headden. B. 35, 1896.
- Alfalfa. (A synopsis of bulletin 35.) W. P. Headden. B. 111, 1906.
- Alfalfa. (Results obtained at the Colorado Experiment Station.) W. P. Headden. B. 110, 1906.
- Alfalfa, its growth, composition. and digestibility. J. Cassidy and David O'Brine. B. 8, 1889.
- Alfalfa ; the relation of type to hardiness. P. K. Blinn. B. 181, 1911.
- Alfalfa, sugar beets, cantaloupes. P. K. Blinn. B. 121, 1907.
- Alfalfa and some other hays. W. P. Headden. B. 39, 1897.
- Alfalfa dodder in Colorado. W. W. Robbins and G. E. Eggington. B. 248, 1918.
- Alfalfa seed production. (A progress report.) P. K. Blinn. B. 191, 1913.
- Alfalfa specialist, Report of,
  - 1910. P. K. Blinn. R. 23 :76.
  - 1911. P. K. Blinn. R. 24 :42.
  - 1912. P. K. Blinn. R. 25 :34.
  - 1913. P. K. Blinn. R. 26 :20.
  - 1914. P. K. Blinn. R. 27 :21.
  - 1915. P. K. Blinn. R. 28 :18.
  - 1916. P. K. Blinn. R. 29 :12.
  - 1917. P. K. Blinn. R. 30:16.
- Alfalfa studies. P. K. Blinn. B. 128, 1908.
- Alfalfa studies, third progress report. P. K. Blinn. B. 154, 1910.
- Alford, Fred C.
  - Extraction of beeswax. B. 129, 1908.
- Algae—
  - destruction by copper sulphate. B. 211:7, 1915.
  - soil—
    - description. Colored plates. B. 184 :27, 1912.
    - source of energy for *Azotobacter*. B. 184 :35, 1912.
- Algae in some Colorado soils. W. W. Robbins. B. 184 :24, 1912.
- Alkali—
  - arsenic soluble in. B. 131 :31, 1908.
  - black—
    - caused by water. B. 231 :10, 1917.
    - poisonous to plants. B. 231 :6. 1917.
    - remedy. B. 231 :14, 1917.
  - effect of drainage on. B. 72 :3, 1902.
  - effect on concrete. B. 132 :3, 1908.
  - effect on sugar beets. B. 183 :5, 1912.

Alkali (Continued)—
- excess of—
  - caused by lack of drainage. B. 239:46, 1918.
- incrustation analysis. B. 72:30, 1902.
- live stock poisoned by. B. 113:22. 1906.
- origin of B. 239:6, 1918; B. 239:41, 1918.
- relation to nitrogen fixation. B. 186, 1913.
- Rio Grande Valley. B. 230:14, 1917.
- soils. See Soils, alkali.
- white—
  - non injurious. B. 230:46, 1917; B. 231:5, 1917; B. 239:29, 1918.

Alkalis in Colorado. W. P. Headden. B. 239, 1918.

ALLISON INGA MARIE KATRENE.
- Home economics section, Report of. R. 30:27, 1917.

Alopecurus—
- *alpinus,* description. B. 12:95, 1890.
- *aristulatus,* description. B. 12:91, 1890.

Alternaria—
- cause of apple rot. B. 105, 1905.
- experiments with. B. 118:6, 1907.
- notes. P. B. 43. 1907.
- undescribed species. B. 105, 1905.

Alypia actomaculata. See Eight-spotted forester.

Amanitas—
- description. B. 201:16, 1914.
- varieties. B. 201:18, 1914.

Amid nitrogen—
- in alfalfa. B. 35:22, 1896; B. 111:6, 1906; B. 124:19, 1907.
- in wheat. B. 217:30, 1916.

Ammonia in ground water. B. 72:42, 1902.

Ammoniacal copper carbonate, preparation. B. 212:53, 1915.

Ammonification in soils. B. 184, 1912; B. 196:14, 1914.

Ammonifying efficiency of certain Colorado soils. Walter G. Sackett. B. 184, 1912.

Ammonium—
- carbonate, nitrification in soils. B. 193:27, 1914.
- chlorid, nitrification in soils. B. 193:26, 1914.

Ammophila longifolia, description. B. 12:99, 1890.

Amphicerus bicaudatus. See Apple-twig borer.

Anarsia lineatella. See Peach-twig borer.

Anasa tristis. See Squash bug.

Ancylis comptana. See Strawberry leaf-roller.

Andropogon—
- *furcatus,* description. B. 12:96, 1890.
- *halapensis.* See Johnson grass.
- *scoparius,* description. B. 12:96, 1890.
- *sorghum,* poisoning in cattle. B. 211:17, 1915.

Animal husbandry section. Report of,
- 1906. H. M. Cottrell. R. 19:161.
- 1907. G. E. Morton. R. 20:42.
- 1908. G. E. Morton. R. 21:33.
- 1909. G. E. Morton. R. 22:61.
- 1910. G. E. Morton. R. 23:83.
- 1911. G. E. Morton. R. 24:71.
- 1912. G. E. Morton. R. 25:48.
- 1913. G. E. Morton. R. 26:25.
- 1914. G. E. Morton. R. 27:37.
- 1915. G. E. Morton. R. 28:27.
- 1916. No report.
- 1917. G. E. Morton. R. 30:21.
- 1918. G. E. Morton. R. 31:16.

Animal poisoning—
- conditions of B. 211:3. 1915.
- prevention of. B. 211:5, 1915.

ANNIS, FRANK J.
- Concerning the duties of the secretary of the State Board of Agriculture and the distribution of college seeds and plants. B. 3, 1887.

Anthracnose. B. 195:18, 1914.

Anthrenus scrophulariae. See Carpet beetle.

Aphis—
- *avenae.* See Grain aphis, European.
- *bakeri.* See Clover aphis.
- *brassicae.* See Cabbage aphis.
- *cucumeris.* See Melon louse.
- *gossypii.* See Melon aphis.
- *mali.* See Apple plant louse.
- *medicagnis.* See Sweet clover aphis.
- *persicae-niger.* See Peach aphis, black.
- *pomi.* See Apple aphis. green.
- *pyri.* See Apple aphis, rosy.
- *setariae.* See Plum aphis, rusty brown.
- woolly *(Schizoneura langiera)*—
  - description. B. 47:16, 1898; B. 114:14, 1906.
  - injuries by. B. 133:11, 1908.
  - life history. B. 119:14, 1907; B. 133:5, 1908; (colored plates) B. 134:4, 1908.

Aphis (Continued)—
- Woolly *(Schizoneura langiera)* (Con't)
  - natural enemies. B. 133 :12, 1908.
  - notes. R. 6:54, 1893 ; R. 17 :92, 1904 ; P. B. 31, 1907 ; B. 210 : 23, 1915.
  - remedies. B. 71 :12, 1902 ; B. 119 :14, 1907 ; B. 133 :18, 1908 ; B. 134:5, 1908.

Apiary experiments. B. 5 :8, 1887.

Apiary section. Report of.
- 1888. C. M. Brose. R. 1 :227.
- 1889. C. M. Brose. R. 2 :80.
- 1890. C. M. Brose. R. 3 :55.
- 1894. C. P. Gillette. R. 7 :63.
- 1898. C. P. Gillette. R. 11 :164.

Apocynum androsaemigolium. See Dogbane.

Apple—
- aphis, green *(Aphis pomi)*—
  - description and remedies. B. 114 :8, 1906 ; B. 210 :15, 1915.
  - food plants. B. 133 :23, 1908.
  - life history. B. 119 :12 1907 ; B. 133 :24, 1908 ; B. 134 :11, 1908.
  - natural enemies. B. 133 :26, 1908.
  - notes. P. B. 31, 1907.
  - remedies. B. 119 :13, 1907 ; B. 133 :27, 1908.
- aphis, rosy *(Aphis pyri)*—
  - description. B. 133 :31, 1906.
  - notes. B. 210 :16, 1915.
- blight—
  - description. B. 41 :3, 1898.
  - treatment. B. 41 :13, 1898.
- curculio. B. 210 :8, 1915.
- flea beetle *(Haltica ignita)*—
  - description and remedies. B. 47 :5, 1898 ; B. 71 :8, 1902 ; B. 114 ; 8, 1906 ; B. 210 :14, 1915.
- juices, analysis. B. 192 :7, 1913.
- leaf-beetle *(Graptodera foliacea).* B. 6 :11, 1888.
- leaf-hopper, description. B. 210 :15, 1915.
- plant lice *(Aphis mali)*—
  - description. B. 47 :16, 1898.
  - remedies. B. 71 :8, 1902.
  - varieties. B. 133 :5, 1908 ; B. 134:4, 1908.
- plant louse. See Apple aphis, green.
- rot *(Alternaria)*—
  - control of. B. 105 :12, 1905 ; B. 212 :11, 1915.
  - description. B. 105 :3, 1905.
  - effect on pear. B. 105 :7, 1905.
  - varieties of apples affected by. B. 105 :11, 1905.

Apple (Continued)—
- tree—
  - borer, flat-headed. See Borer, flat-headed.
  - root rot, description. B. 69 :4, 1902.
  - rosette. B. 69 :6, 1902.
- trees—
  - pruning. B. 139 :6, 1909.
  - root system. B. 173 :4, 1910.
- twig—
  - blight, notes. R. 1 :64, 1888.
  - borer *(Amphicerus bicaudatus)*
    - description and remedies. B. 47 :10, 1898 ; B. 71 :10, 1902 ; B. 114 :12, 1906.
    - notes. R. 13 :126, 1900.
- worm. See Codling moth.

Apples—
- blooming season of. R. 24 :60, 1911.
- crab. See Crab apples.
- culture. B. 223 :27, 1917.
- fungous diseases of. B. 212 :11 1915.
- insects injurious to. B. 71 :6, 1902 ; B. 114 :6, 1906 ; B. 210 :5, 1915.
- thinning. B. 118 :12, 1907.
- varieties. B. 17 :26, 1891 ; B. 21 :14, 1892 ; B. 223 :44, 1917.
- winesap, thinning. B. 170, 1910.

Apricot—
- blight. B. 84, 1903.
- trees, pruning. B. 139 :7, 1909.

Apricots—
- fungous diseases of. B. 212 :14, 1915.
- insects injurious to. B. 210 :24, 1915.
- pear blight affecting. B. 84 :5, 1903.
- varieties. B. 17 :34, 1891 ; B. 223 :46, 1917.

Arapahoe County—
- agriculture. B. 59 :11, 1900.

Archips argyrospila. See Fruit tree leaf-roller.

Arid farming. See Dry farming.

Aristida—
- *basiramea,* description. B. 12 :117, 1890.
- *longiseta.* See Wire grass.

Arkansas River—
- seepage—
  - gains and losses. B. 180, pt. 1 :42, 1911 ; B. 180, pt. 3 :143, 1911.
  - measurement. R. 11 :190, 1898 ; R. 12:47, 1899.
- **water—**
  - analysis. B. 82 :62, 1903 ; B. 230 :5, 1917 ; B. 132 :6, 1908.
  - measurement, 1897-1904. B. 180, pt. 3 :92, 1911.

- Arkansas Valley—
  - rainfall, annual, 1880-1910. B. 180, pt. 1:45, 1911; B. 180, pt. 3:146, 1911.
  - soil analysis. B. 42:33, 1898.
  - sugar beets, notes. B. 42:12, 1898.
  - tomato industry in. B. 78, 1903.
  - water resources, description. B. 180, pt. 1:17, 1911.
- Arkansas Valley Experiment Station—
  - meteorological observations. R. 3:155, 1890; R. 4:61, 1891.
  - report,
    - 1888. Frank Watrous. R. 1:237.
    - 1889. Frank Watrous. R. 2:113.
    - 1890. Frank Watrous. R. 3:202.
    - 1891. Frank Watrous. R. 4:104.
    - 1892. F. A. Huntley. R. 5:41.
    - 1893. F. A. Huntley. R. 6:61.
    - 1894. F. A. Huntley. R. 7:89.
    - 1905. P. K. Blinn. R. 18:62.
    - 1896. P. K. Blinn. R. 9:159.
    - 1897. W. F. Crowley. R. 10:86.
    - 1898. H. H. Griffin. R. 11:219.
    - 1899. H. H. Griffin. R. 12:55.
    - 1900. H. H. Griffin. R. 13:141.
    - 1901. H. H. Griffin. R. 14:42.
    - 1902. H. H. Griffin. R. 15:143.
    - 1903. P. K. Blinn. R. 16:31.
  - report of field agent,
    - 1904. P. K. Blinn. R. 17:111.
    - 1905. P. K. Blinn. R. 18:62.
    - 1906. P. K. Blinn. R. 19:167.
    - 1907. P. K. Blinn. R. 20:48.
    - 1908. P. K. Blinn. R. 21:21.
- Arkansas Valley Sub-station, meteorological observations. See Rocky Ford, meteorological observations.
- Army cutworm. See Cutworm, army.
- Army worm *(Leucania unipuncta)*—
  - notes. R. 6:53, 1893.
- Arsenate of lead. See Lead arsenate.
- Arsenic—
  - bran mash—
    - for grasshoppers. B. 233:15, 1917.
    - notes. B. 71:21, 1902; B. 114:29, 1906.
  - effect on fruit trees. B. 131, 1908; B. 157, 1910.
  - made soluble by alkalies. B. 131:21, 1908; B. 157:28, 1910.
  - poisoning, systemic. B. 157:42, 1910.
  - white, notes. B. 71:21, 1902; B. 114:28, 1906; B. 210:42, 1915.
- Arsenical—
  - poisoning of fruit trees—
    - description. B. 131:9. 1908; B. 157:5, 1910.
    - effect. B. 157:14, 1910.
- Arsenical poisoning of fruit trees. W. P. Headden. B. 131, 1908.
- Arsenical poisoning of fruit trees. W. P. Headden. B. 157, 1910.
- Arsenite of lime. See Lime, arsenite.
- Arsenoid, green. See Scheele's green.
- Artesian—
  - water—
    - brown, analysis. B. 230:35, 1917.
    - San Luis Valley, analysis. B. 230:29, 1917.
    - white, analysis. B. 230:30, 1917.
  - wells—
    - description. B. 16:3, 1891.
    - in Colorado. B. 16:12, 1891.
      - Denver basin. B. 16:15, 1891.
      - San Luis basin. B. 16:17, 1891.
    - irrigation from. B. 16:6, 1891.
- Artesian wells of Colorado and their relation to irrigation. L. G. Carpenter. B. 16, 1891.
- *Asclepias.* See Milkweed.
- Asparagus—
  - culture. B. 199:4. 1914; B. 241:12, 1918.
  - fungous disease of. B. 212:14. 1915.
  - notes. B. 172:4, 1910.
  - rust *(Puccinia asparagi)*—
    - notes. B. 69:11, 1902; B. 212:14, 1915.
- *Aspidiotus*—
  - *ancylus.* See Putnam scale.
  - *howardi.* See Howard scale.
  - *perniciosus.* See San Jose scale.
- Aster wilt *(Fusarium.)* B. 69:12, 1902.
- *Athysanus ornatus.* B. 43:29, 1898.
- Atmospheric evaporation. B. 1:9, 1887. *See also* Meteorological observations.
- *Atriplex argentea.* See Saltbush.
- Australian saltbush, its composition and digestibility. Notes on Russian thistle. W. P. Headden. B. 135, 1908.
- *Avena elatior.* See Oat grass, tall.
- *Azotobacter*—
  - algae as a source of energy for. B. 184:35, 1912.
  - *chrococcum*—
    - nitrogen fixation in soils. B. 179:32, 1911.
- Azusa hydrant—
  - water measurement. B. 207:12, 1915.
- Babcock's milk test. B. 20:4, 1892.
- Bacteria, description. B. 196:3, 1914.

A bacterial disease of alfalfa. Walter G. Sackett. B. 158, 1910.

Bacterial stem blight of field and garden peas. Walter G. Sackett. B. 218, 1916.

Bacteriological section, Report of.
- 1908. W. G. Sackett. R. 21 :145.
- 1909. W. G. Sackett. R. 22 :48.
- 1910. W. G. Sackett. R. 23 :91.
- 1911. W. G. Sackett. R. 24 :16.
- 1912. W. G. Sackett. R. 25 :21.
- 1913. W. G. Sackett. R. 26 :16.
- 1914. W. G. Sackett. R. 27 :18.
- 1915. W. G. Sackett. R. 28 :11.
- 1916. W. G. Sackett. R. 29 :22.
- 1917. W. G. Sackett. R. 30 :20.
- 1918. W. G. Sackett. R. 31 :18.

Bacteriological studies of the fixation of nitrogen in certain Colorado soils. Walter G. Sackett. B. 179, 1911.

Bacterium teutlium. See Sugar beets, soft rot.

BAINER, H. M.
- Farm butter making. B. 163, 1910.
- Farm machinery report and dairying. R. 22 :62, 1909.
- —and BONEBRIGHT, H. B.
- Cement and cement fence posts. B. 161, 1910.
- Cement and concrete fence posts. B. 148, 1909.
- Life and care of farm machinery in Colorado. B. 167, 1910.

BAKER, CARL F. See Gillette, C. P. jt. author. B. 31, 1895.

BAKER, CHARLES FULLER. See Baker, Carl F.

Balsam firs. See Firs, balsam.

Bark-boring beetles, notes. R. 15 :115, 1902.

Barley—
- crosses. Mendelian characteristics. B. 249 :16, 1918.
- culture—
  - experiments. B. 2 :11, 1887.
  - San Luis Valley. B. 209 :27, 1915.
- feeding value. B. 40 :15, 1897.
- for—
  - lambs. B. 187 :12, 1913.
  - pigs. B. 74, 1902.
- fungous diseases of. B. 212 :22, 1915.
- notes. B. 30 :4, 1894.
- smut control. B. 238 :28, 1918.
- varieties. R. 1 :54, 1888 ; B. 26 :6, 1894 ; B. 40 :5, 1897.
- wild. See Squirrel-tail grass.

Barley. W. W. Cooke. B. 40, 1897.

Barn-yard—
- grass *(Panicum crus-galli.)* B. 12 : 34, 1890.
- manure, value of. B. 99 :10, 1905.

BARNES, C. L. See Glover, Geo. H. jt. author. B. 137, 1909.

Barograph, description. B. 49 :9, 1898.

Barometer. description. B. 49 :9, 1898.

BASHOR, M. E.
- San Luis Valley Experiment Station, Report of, R. 4-5, 1891-1892.

BEACH, FRANK.
- San Luis Valley Experiment Station, Report of, R. 6, 1893.

Bean—
- anthracnose. B. 226 :25, 1917.
  - control. B. 238 :22, 1918.
  - description. B. 234 :26, 1918.
- bacteriosis. B. 138 :21, 1909 ; B. 226 :22, 1917.
  - control B. 238 :23, 1918.
  - description. B. 234 :26, 1918.
- beetle—
  - description and remedies. B. 47 :41, 1898 ; B. 19 :25, 1892.
  - spotted *(Epilachna corrupta.)* B. 199:42, 1914.
- blight. See Bean bacteriosis.
- diseases, control. B. 226 :29, 1917 ; B. 234 :31, 1918.
- pod spot. See Bean anthracnose.
- rust. B. 226 :27, 1917 ; B. 234 :28, 1918.
- spot. See Bean anthracnose.
- Straw—
  - uses of. B. 226 :17, 1917 ; B. 234 :20, 1918.
- streak. B. 226 :27, 1917 ; B. 234 :30, 1918.

Beans—
- culture. B. 226 :6, 1917 ; B. 234 :8, 1918 ; B. 241 :13, 1918.
- diseases of. B. 234 :23, 1918.
- experiments. B. 2 :3, 1887.
- fungous diseases of. B. 212 :15, 1915.
- harvesting B. 226 :11, 1917 ; B. 234 :12, 1918.
- marketing. B. 226 :15, 1917.
- notes. B. 172 :5, 1910 ; B. 199 :6, 1914.
- production cost. B. 226 :16, 1917 ; B. 234 :19, 1918.
- soil preparation for. B. 234 :6, 1918.
- thrashing. B. 226 :14, 1917 ; B. 234 : 16, 1918.
- varieties. B. 26 :14, 1894 ; B. 226 :5, 1917 ; B. 234 :6, 1918.

Beans in Colorado and their diseases. Alvin Kezer and Walter G. Sackett. B. 226, 1917.
Beans in Colorado and their diseases. Alvin Kezer and Walter G. Sackett. B. 234, 1918.
Bear Creek—
  seepage—
    gains and losses 1900-1910. B. 180, pt. 1 :40, 1911 ; B. 180, pt. 3 :141, 1911.
    measurement 1900. B. 13 :138, 1900.
  water measurement 1900-1910. B. 180, pt. 3:54, 1911.
Beard grass *(Polypogon monspeliensis.)* B. 12 :99, 1890.
Beckmannia erucaeformis. See Water grass.
Bedbugs *(Acanthia lectularia.)* B. 47 : 51, 1898.
Bee—
  paralysis, notes. R. 10 :60, 1897.
  plants, list. R. 15 :119, 1902.
  See also Bees.
Beef—
  production cost. B. 189 :6, 1913.
  products shipped in Colorado. B. 153 :6, 1910.
Bees—
  artificial comb foundation. B. 54 :3, 1900.
  culture experiments. B. 54, 1900.
  long-tongued. R. 14 :15, 1901.
  management. B. 5 :8, 1887.
  Nomada genus in Colorado. B. 94 : 69, 1904.
  swarming control. B. 5 :8, 1887.
  See also Apiary report ; Bee.
Bees of the genus *Nomada* found in Colorado. T. D. A. Cockerell. B. 94, 1904.
Beeswax—
  bleaching. B. 129 :10, 1908.
  color. B. 129 :9, 1908.
  extraction—
    solar extractor. B. 129 :4, 1908.
    steam extractor. B. 129 :7, 1908.
Beet—
  army-worm. P. B. 3, 1900 ; B. 64 :10, 1901.
    Caradrina exigua. B. 98 :13, 1905.
    Laphygma flavimaculata. R. 12 :39, 1899.
      remedies. B. 98 :15, 1905.
Beet (Continued)—
  web-worm *(Loxostege sticticalis)*—
    description. B. 98 :3, 1905 ; B. 94 :11, 1904.
    remedies. B. 98 :8, 1905.
  See also Beets ; Sugar beets.
Beet army-worm. C. P. Gillette. P. B. 3, 1900 ; B. 64 :10, 1901.
Beet army-worm. Beet web-worm. C. P. Gillette. B. 98, 1905.
Beet pulp and sugar beets for fattening hogs. Home grown grain vs. corn for fattening hogs. Other trials with corn, barley, alfalfa, and beets. Swine feeding in Colorado. B. C. Buffum and H. H. Griffin. B. 74. 1902.
Beet web-worm. Beet army-worm. C. P. Gillette. B. 98, 1905.
Beets—
  experiments. B. 2 :4, 1887.
  fungous diseases of. B. 212 :17, 1915.
  notes. B. 30 :6, 1894 ; B. 172 :5, 1910 ; B. 199 :7, 1914 ; B. 241 :14, 1918.
  See also Beet ; Sugar beets.
BENNETT, E. R.
  Cabbage growing. B. 143. 1909.
  Colorado potato industry. B. 117, 1907.
  Garden notes. B. 172, 1910.
  Horticultural section, Report of, R. 22-25, 1909-1912.
  Onions in Colorado. B. 198, 1914.
  Potato investigations report. R. 19-21, 1906-1908.
  Potatoes on the plains ; suggestions to new settlers. P. B. 37, 1907 ; Same. B. 123 :14, 1907.
  —See Fitch, C. L. jt. author. B. 175, 1910.
  —See Herrick, Robert S. jt. author. B. 171, 1910.
Bent Agricultural Experiment Station. See Arkansas Valley Experiment Station.
Best milk tester for the practical use of the farmer and dairyman : The influence of food upon the pure fat present in milk. Walter J. Quick. B. 20, 1892.
Best time to cut alfalfa. W. P. Headden. P. B. 13, 1902.
Big Thompson River—
  Seepage—
    gains and losses 1897-1910. B. 180, pt. 1 :36, 1911 ; B. 180, pt. 3 :137, 1911.
    measurements. R. 11 :191, 1898 ; R. 12:45, 1899 ; R. 13 :136, 1900.

- Big Thompson River (Continued)—
  - water—
    - analysis. B. 82 :60, 1903.
    - measurement 1900-1910. B. 180, pt. 3 :1, 1911.
- Birds—
  - bibliography. B. 37 :20, 1897; B. 44 :151, 1898; B. 56 :186, 1900.
  - Colorado. B. 37 :49, 1897; B. 44 : 155, 1898; B. 56 :191, 1900.
    - classification. B. 37 :8, 1897; B. 44 :148, 1898; B. 56 :182, 1900.
  - dates of arrival in Colorado. B. 37 :18, 1897.
  - dates of migration from Colorado. B. 37 :17, 1897.
- Birds of Colorado. W. W. Cooke. B. 37, 1897.
- Birds of Colorado. W. W. Cooke. B. 56, 1900.
- "Black alkali" in the San Luis Valley. W. P. Headden. B. 231, 1917.
- Black cherry louse. See Cherry aphis.
- Black peach aphis. See Peach aphis, black.
- Blackberries—
  - culture. B. 195 :7, 1914.
  - fungous diseases of. B. 212 :18, 1915.
  - varieties. B. 17 :35, 1891; B. 60 :10, 1900.
- Blackberry—
  - root disease *(Rhizoctonia)* B. 69 :9, 1902.
- Blackleg, notes. B. 137 :8, 1909.
- Blight and other plant diseases. C. S. Crandall. B. 41, 1898.
- BLINN, PHILO K.
  - Alfalfa; the relation of type to hardiness. B. 181, 1911.
  - Alfalfa, sugar beets, cantaloupes. B. 121, 1907.
  - Alfalfa seed production. (A progress report.) B. 191, 1913.
  - Alfalfa specialist report. R. 23-30, 1910-1917.
  - Alfalfa studies. B. 128, 1908.
  - Alfalfa studies, third progress report. B. 154, 1910.
  - Arkansas Valley Experiment Station report. R. 8-9, 1895-1896.
  - Arkansas Valley field agent report. R. 15-21, 1902-1908.
  - Cantaloupe breeding. B. 126, 1908.
  - Cantaloupe seed. B. 85, 1903.
  - Development of the Rocky Ford cantaloupe industry. B. 108, 1906.
  - Early cantaloupes. B. 95, 1904.
- BLINN, PHILO K. (continued)—
  - A hopperdozer. B. 112, 1906.
  - A rust resisting cantaloupe. B. 104, 1905.
- Blister Beetles. B. 6 :19, 1888.
- Blood, dried—
  - nitrification in soils. B. 193 :29, 1914; B. 193 :36, 1914.
- BLOUNT, A. E.
  - Agricultural section, Report of, R. 1-2, 1888-1889.
  - Report of experiments with grains, grasses, and vegetables. B. 2, 1887.
- Blue—
  - bean. See Lupines.
  - joint *(Deyeuxia canadensis.)* B. 12:48, 1890.
- Boar, feed and management. B. 146 :11, 1909.
- Bog rush *(Juncus mertensianus)*—
  - description and analysis. B. 12 :126, 1890.
- BONEBRIGHT, H. B.
  - parafine-lined vinegar cistern. P. B. 54, 1910.
  - —See Bainer, H. M. jt. author. B. 161, 1910. B. 167, 1910.
- Borax—
  - as an insecticide. B. 71 :26, 1902. B. 114 :34, 1906.
- Bordeau mixture—
  - cost of materials. B. 206 :22, 1915.
  - effect on apples. B. 69 :9, 1902.
  - effect on raspberries. B. 206 :21, 1915.
  - formula. B. 69 :22, 1902.
  - notes. B. 71 :25, 1902; B. 114 :33, 1906; B. 210 :44, 1915; B. 212 :50, 1915.
- Borer, flat headed *(Chrysobthris femorata)*—
  - description and remedies. B. 47 :8, 1898; B. 71 :10, 1902; B. 114 :13, 1906.
  - notes. B. 210 :24, 1915.
- Botanical and horticultural section—
  - department work. Spec. B. "A" :4, 1892. B. 5 :4, 1887.
- Botanical and horticultural section, Report of,
  - 1888. James Cassidy. R. 1 :57.
  - 1889. C. M. Brose. R. 2 :22.
  - 1890. C. S. Crandall. R. 3 :29.
  - 1891. C. S. Crandall. R. 4 :17.
  - 1892. C. S. Crandall. R. 5 :26.
  - 1893. C. S. Crandall. R. 6 :39.
  - 1894. C. S. Crandall. R. 7 :47.
  - 1895. C. S. Crandall. R. 8 :104.
  - 1896. C. S. Crandall. R. 9 :121.
  - 1897. C. S. Crandall. R. 10 :48.

Botanical and horticultural section, Report of, (continued)
- 1898. C. S. Crandall. R. 11 :135.
- 1899. C. S. Crandall. R. 12 :32.
- 1900. Wendell Paddock. R. 13 :122.
- 1901. Wendell Paddock. R. 14 :40.
- 1902. Wendell Paddock. R. 15 :128.
- 1903. Wendell Paddock. R. 16 :22.
- 1904. Wendell Paddock. R. 17 :97.
- 1905. Wendell Paddock. R. 18 :43.
- 1906. Wendell Paddock. R. 19 :133.
- 1907. Wendell Paddock. R. 20 :27.
- 1908. Wendell Paddock. R. 21 :141.
- For later reports *see* Horticulture and potato investigations, *and* Horticultural section, Report of.

Botanical section, Report of,
- 1909. B. O. Longyear. R. 22 :43.
- 1910. B. O. Longyear. R. 23 :94.
- 1911. B. O. Longyear. R. 24 :35.
- 1912. B. O. Longyear. R. 25 :49.
- 1913. B. O. Longyear. R. 26 :28.
- 1914. B. O. Longyear. R. 27 :30.
- 1915. W. W. Robbins. R. 28 :14.
- 1916. W. W. Robbins. R. 29 :24.
- 1917. W. W. Robbins. R. 30 :22.
- 1918. W. W. Robbins. R. 31 :20.

Boulder Creek—
- seepage—
  - gains and losses 1900-1907. B. 180, pt. 1 :38, 1911 ; B. 180, pt. 3 :139, 1911.
  - measurement. R. 13 :138, 1900.
- water—
  - analysis. B.. 82 :61, 1903.
  - measurement 1900-1907. B. 180, pt. 3 :35, 1911.

Bouteloua—
- *hirsuta.* See Grama grass.
- *oligostachya.* See Grama grass.
- *racemosa.* See Grama grass.

Box-elder—
- leaf-roller—
  - *(Cacaecia semiferana.)* B. 19 : 10, 1892.
  - *(Cacaecia senifera)* B. 6 :17, 1888.
- plant bug *(Leptocoris trivittatus.)* B. 47 :32, 1898.

Boyack, Breeze. See Kezer, Alvin. jt. author. B. 249, 1918.

Bran mash, poison. B. 210 :43, 1915.

Breakfast foods. See Cereal foods.

Breninger, George F.
- Divide Experiment Station report. R. 4-5, 1891-1892.

Brisket disease—
- cause. B. 204 :10, 1915 ; B. 229 :4, 1917.

Brisket disease (continued)—
- description. B. 204 :3, 1915.
- report of cases. B. 204 :16, 1915.
- symptoms. B. 229 :5, 1917.
- treatment. B. 204 :8, 1915 ; B. 229 :6, 1917.

Brisket disease (Dropsy of high altitudes.) Geo. H. Glover and I. E. Newsom. B. 204, 1915.

Brisket disease. Geo. H. Glover and I. E. Newsom. B. 229, 1917.

Brome grass—
- downy *(Bromus tectorum.)* B. 211 : 21, 1915.
- smooth *(Bromus inermis)*—
  - description. B. 61 :3, 1900.
  - experiments at Arkansas Valley Sub-station. B. 61:6, 1900.
  - experiments at Fort Collins station. B. 61 :5, 1900.
  - experiments at Plains station. B. 61 :8, 1900.
  - variation studies. B. 190, 1913.

Bromus—
- *breviaristatus,* description. B. 12 :51, 1890.
- *ciliatus,* description. B. 12 :51, 1890.
- *inermis.* See Brome grass, smooth.
- *kalmii* var. *porterii,* description. B. 12 :53, 1890.
- *mexicana.* description. B. 12 :52, 1890.
- *secalinus.* See Chess.
- *tectorum.* See Brome grass, downy.
- *unioloides,* description. B. 12 :52, 1890.

Bromus inermis. F. L. Watrous, H. H. Griffin, and J. E. Payne. B. 61, 1900.

Broom corn—
- notes. B. 2 :6, 1887.
- on plains lands. B. 214 :23, 1915.
- shipped into Colorado 1909. B. 153 :12, 1910.

Brose, Charles Max.
- Apiary report. R. 1-3, 1888-1890.
- Botanical and Horticultural section, Report of. R. 2, 1889.
- Report of experiments in apiary. B. 5, 1887.

Brown mite. See Clover mite.

Bruchus pisi. See Pea weevil.

Bruner, Lawrence.
- Some new Colorado *Orthoptera.* B. 94 :57, 1904.

Brussels sprouts, notes. B. 199 :8, 1914. B. 241 :15, 1918.

Bryobia pratensis. See Clover mite.

Buchloe dactyloides. See Buffalo grass.

Buckbean *(Thermopsis.)* B. 211 :49, 1915
Buckwheat—
    notes. B. 2 :9, 1887 ; B. 30 :5, 1894.
    varieties. B. 30 :5, 1894.
Budding and grafting. B. 147 :12, 1909.
Buffalo—
    bur *(Solanum rostratum.)* B. 23 :10, 1893.
    grass *(Buchloe dactyloides.)* B. 12 : 136, 1890.
    in Colorado. B. 87 :10, 1904.
    tree hopper *(Ceresa bubalus)*—
        description and remedies. B. 47 :11, 1898 ; B. 71 :11, 1902 ; B. 114 :13, 1906.
Buffum, Burt C.
    Agricultural section, Report of, R. 13-14, 1900-1904.
    Tuberculin tests of the college herd. B. 66, 1901.
    —and Griffith, Clarence J.
    Feeding value of beet pulp. Feeding beet pulp and sugar beets to cows. B. 73, 1902.
    Lamb feeding experiments 1900-1902. Sugar beets and beet pulp. Home grown grains and corn. Small grain and corn. Warm and cold water. Shropshire grades and native lambs. B. 75, 1902.
    Swine feeding in Colorado. Beet pulp and sugar beets for fattening hogs. Home grown grain vs. corn for fattening hogs. Other trials with corn, barley, alfalfa, and beets. B. 74, 1902.
Buhach. See Pyrethrum.
Bull pine. See Pines, bull.
Bunch grass *(Poa tenuifolia.)* B. 12 :26, 1890.
Bush fruits, including gooseberries, raspberries, blackberries, dewberries, Carl H. Potter. B. 60, 1900.
Butter—
    churning. B. 163 :9. 1910.
    making—
        farm. B. 163 :3, 1910.
        pasteurization in. B. 156 :13, 1910.
        skimming milk for. B. 163 :5, 1910.
    ripening of cream for. B. 163 :8, 1910.
    starters, commercial—
        description. B. 156 :9, 1910.
        kinds of. B. 156 :14. 1910.
        propagation. B. 156 :11, 1910.
Butter making, clean milk and commercial starters. Walter G. Sackett. B. 156, 1910.
Bythoscopidae in college collection. B. 43 :30, 1898.
Cabbage—
    aphis *(Aphis brassicae.)* B. 47 :44, 1898 ; B. 199 :42, 1914.
    black rot—
        control. B. 238 :23, 1918.
        notes. B. 138 :15, 1909.
    butterfly, imported *(Pieris rapae)*—
        description and remedies. B. 6 :8, 1888 ; B. 24 :3, 1893 ; B. 47 :45, 1898.
        notes. B. 199 :41, 1914.
    butterfly, Southern *(Pieris protodice)*—
        description and remedies. B. 6 :15, 1888 ; B. 24 :7, 1893.
    flea-beetle *(Phyllotreta albionica.)* B. 24 :12, 1893.
    plusia *(Plusia brassicae.)* B. 24 :8, 1893.
    plutella *(Plutella cruciferarum.)* B. 24:9, 1893 ; B. 47 :46, 1898.
    louse. See Cabbage aphis.
    worm, imported See Cabbage butterfly, imported.
Cabbage breeding experiments.
    1911. S. V. Smith. R. 24 :64.
    1912. S. V. Smith. R. 25 :42.
Cabbage growing. E. R. Bennett. B. 143, 1909.
Cabbages—
    breeding experiments. B. 172 :14, 1910.
    cost of growing on college farm. B. 203 :17, 1914 ; (tables.)
    cultivation. B. 143 :3, 1909.
    diseases. B. 143 :6. 1909.
    fungous diseases of. B. 212 :19, 1915.
    insects injurious to B. 143 :6, 1909.
    irrigation. B. 143 :5 ,1909.
    notes. B. 26 :21, 1894 ; B. 172 :5, 1910 ; B. 199 :8, 1914 ; B. 241 :15, 1918.
    varieties. B. 26 :21, 1894.
Cacaecia—
    semiferana. See Box-elder leaf-roller.
    senifera. See Box-elder leaf-roller.
Cache a la Poudre River—
    discharge and depth. R. 3 :61, 1890.
    flow chart. B. 55 :5, 1900.
    seepage—
        gains and losses. R. 12 :42, 1899 ; B. 180, pt. 1 :36, 1911 ; B. 180, pt. 2, 1911.
        measurement. R. 11 :195, 1898 ; R. 13 :136, 1900.

Cache a la Poudre River (Continued)-
- water—
  - analysis. B. 82 :12. 1903 ; B. 230 :4, 1917.
  - changes because of irrigation. B. 82, 1903.

Cache a la Poudre Valley—
- canal seepage. B. 48 :7, 1898.
- irrigation development. B. 180, pt. 1 :21, 1911.
- irrigation system. B. 33 :7, 1896 ; B. 33 :16, 1896.
- onion culture in. B. 81, 1903.
- water—
  - distribution. B. 33 :37, 1896.
  - for irrigation. B. 22 :21, 1893.
  - measurement. B. 33 :14, 1896 ; B. 180, pt. 2, 1911.
  - resources. B. 180, pt. 1 :12, 1911.

Cacoecia argyrosphila. See Fruit-tree leaf-roller.

Caeoma nitens. See Orange rust.

Calcium compounds in soils. B. 196 :38, 1914.

Calves—
- diptheria—
  - description. B. 107 :14, 1914 ; B. 197 :13, 1914.
  - remedies. B. 197 :15, 1914.
- sore mouth disease. B. 137 :3, 1909.

Camas, death. See Death camas.

Campbell, Walter. Test of measurement of water applied to field of. B. 22 :13, 1893.

Canale Villorese See Villorese, canale.

Canals—
- construction cost. R. 3 :77, 1890.
- frictional resistance in. B. 194, 1914.
- losses from seepage. B. 48, 1898 ; R. 11:195, 1898.
- milage in Colorado. R. 3 :75, 1890.

Canary grass *(Phalaris canariensis.)* B. 12 :88, 1890.

Canned goods shipped into Colorado. B. 153 :18, 1910.

Cantaloupe—
- blight—
  - cost of spraying. B. 62 :12, 1901.
  - experiments. B. 62 :8, 1901.
  - investigations. B. 104 :5, 1905.
  - notes. P. B. 4, 1900 ; B. 64 :12, 1901 ; B. 62 :7, 1901 ; B. 68 : 12, 1902.
  - remedies. P. B. 4. 1900 ; B. 64 : 12, 1901.
  - spray formula. B. 62 :15, 1901.

Cantaloupe (Continued)—
- grower's association list. B. 122 :9, 1907.
- pollination. B. 62 :16, 1901.
- rust. See Cantaloupe blight.
- seed selection. B. 85 :5. 1903 ; B. 104 :5, 1905 ; B. 121 :6, 1907.
- seed standard of perfection. B. 85 :6, 1903.
- wilt, notes. B. 138 :22. 1909.

Cantaloupe blight. H. H. Griffin. P. B. 4, 1900 ; Same. B. 64 :12, 1901.

Cantaloupe blight (Arkansas Valley.) Pasture grasses. Leguminous crops. H. H. Griffin. B. 68, 1902.

Cantaloupe breeding. P. K. Blinn. B. 126, 1908.

Cantaloupe seed. P. K. Blinn. B. 85, 1903.

Cantaloupes—
- artificial fertilization. B. 126 :9, 1908.
- culture. B. 62 :3, 1901 ; B. 95, 1904.
- development. B. 108, 1906.
- experiment to improve. B. 126 :5, 1908.
- from a luxury to a necessity. B. 108 :11, 1906.
- fungous diseases of. B. 212 :20. 1915.
- insect pests. B. 62 :16, 1901.
- market development. B. 108 :14, 1906.
- New York condition. B. 108 :13, 1906.
- rust resisting. B. 104, 1905.
- seed selection. B. 62 :4, 1901.
- transplanting B. 62 :6, 1901.

Cantaloupes. H. H. Griffin. B. 62, 1901.

Capillarity in soils. B. 103 :18, 1905.

Capsella bursa-pasteris. See Shepherd's purse.

Caradrina exigua. See Beet army-worm.

Carbon—
- bisulfide as an insecticide. B. 71 :31, 1902 ; B. 114 :39, 1906 ; B. 210 :50, 1915.
- transformation in soils. B. 196 :9, 1914.

Carex rupestris, analysis. B. 12 :127, 1890.

CARLYLE, WILLIAM L.
- Agricultural section, Report of. R. 17-20, 1904-1907.
- —and GRIFFITH, C. J.
- Feeding steers on sugar beet pulp, alfalfa hay, and ground corn. B. 102, 1905.

Carlyle, William L. (continued.)
  —and Griffith, C. J. and Meyer, A. J.
  Feeding steers on sugar beet pulp, alfalfa hay, and farm grains. B. 97, 1905.
  —and Morton, G. E.
  Carrying range steers through the winter. Sugar beets for fattening steers. B. 149, 1909.
  Ration experiments with lambs, 1906/7, 1907/8, Self feeders for hay. B. 151, 1910.
  Ration experiments with swine. 1906/8. B. 165, 1910.
Carpenter, Louis G.
  Artesian wells of Colorado and their relation to irrigation. B. 16, 1891.
  Colorado sunshine. P. B. 2 in B. 64 :6, 1901.
  Forests and snows. B. 55, 1901.
  Loss of water from reservoirs by seepage and evaporation. B. 45, 1898.
  Losses from canals from filtration or seepage. B. 48, 1898.
  Measurement and division of water. B. 13, 1890.
  Measurement and division of water. B. 27, 1894.
  Meteorological and irrigation engineer report. R. 1-22, 1888-1909.
  On the measurement and division of water. B. 150, 1909.
  Preliminary report on the duty of water. B. 22, 1893.
  Rainfall on the plains. B. 123 :21, 1907.
  Report of the Experiment Station. R. 12-22, 1899-1909.
  Seepage and return waters.
    General discussion and principles. Pt. 1. B. 180, 1911.
    Detailed measurements. The Cache a la Poudre. Pt. 2, B. 180, 1911.
    Detailed measurements. Pt. 3, B. 180, 1911.
  Seepage measurement of the Experiment Station. P. B. 7, 1901; Same, B. 64 :19, 1901.
  Seepage or return waters from irrigation. B. 33, 1896.
  Seepage or return waters on Boulder and South Boulder creeks. P .B. 14, 1902.
  Seepage or return waters on the Uncompahgre River. P. B. 15, 1902.
  Sunshine for 1900. P. B. 9, 1901. Same, B. 64 :23, 1901.
  —and Trimble, R. E.
  Climate of Colorado, temperature. 21 years record at Fort Collins. B. 127, 1908.
  Meteorology of 1897, with illustrations. B. 49, 1898.
Carpet beetle *(Anthrenus scrophularias.)* B. 47 :53. 1898.
Carpocapsa pomonella. See Codling moth.
Carriage Horse Breeding Station—
  Colorado—
    information concerning. B. 166, 1910.
    pedigree stock at. B. 166 :9, 1910.
  See also Horse Breeding Station.
Carrots—
  fungous disease of. B. 212 :20. 1915.
  notes. B. 2 :4, 1887; B. 199 :10, 1914; B. 241 :16, 1918.
Carrying range steers thru the winter. Sugar beets for fattening steers. W. L. Carlyle and G. E. Morton. B. 149, 1909.
Cassidy, James.
  Botanical and horticultural section, Report of. R. 1, 1888.
  Insects and insecticides. B. 6, 1888.
  Potatoes and tobacco. B. 4, 1888,
  —and O'Brine, David.
  Alfalfa; its growth, composition, and digestibility. B. 8, 1889.
  Potatoes and sugar beets. B. 7, 1888.
  Some Colorado grasses and their chemical analysis. B. 12, 1890.
  Tobacco. B. 10, 1890.
Catabrosa aquatica. B. 12 :62, 1890.
Catalpa, pruning. P. B. 41, 1907.
Catsup shipped into Colorado in 1909. B. 153 :21, 1910.
Cattle—
  brisket disease. B. 204 :3, 1915.
  diseases. B. 87 :15, 1904.
  dropsy of. See Brisket disease.
  feeding. B. 34, 1896.
    cost. B. 189 :6, 1913; B. 189 :2, 1913 (tables.)
    experiments. B. 34 :31, 1896; B. 87, 1904; B. 189:3, 1913.
  in eastern Colorado, history. B. 87, 1904.
  marketing. B. 34 :7, 1896.
  tuberculin test. B. 66, 1901.
  wintering. B. 34 :4, 1896; B. 87 :13, 1904; B. 189:4, 1913.
Cattle feeding in Colorado. W. W. Cooke. B. 34, 1896.
Cattle raising on the plains. J. E. Payne. B. 87, 1904.

Cauliflower—
  notes. B. 26 :22, 1894 ; B. 172 :6, 1910 ; B. 199 :10, 1914 ; B. 241 :16, 1918.
  varieties. B. 26 :22, 1894.
Cedar, red. B. 130 :31, 1908.
Celery—
  blanching. B. 144 :8, 1909.
  blight control. B. 238 :24, 1918.
  cost of production. B. 144 :12, 1909.
  culture. B. 144 :3, 1909.
  fungous disease of. B. 212 :20, 1915.
  marketing. B. 144 :11, 1909.
  notes. B. 172 :7, 1910 ; B. 199 :11, 1914 ; B. 241 :17, 1918.
  varieties. B. 144 :4, 1909.
Celery growing in Colorado. L. J. Reid. B. 144, 1909.
Cement. See Concrete.
Cement and concrete fence posts. H. M. Bainer and H. B. Bonebright. B. 148, 1909.
Cement and concrete fence posts. H. M. Bainer and H. B. Bonebright. B. 161, 1910.
Cenchrus tribuloides. See Sand-bur.
Cenopsis testulana. See Choke-cherry leaf-roller.
Cercospora beticola—
  affecting sugar beets. B. 183 :24, 1912.
Cereal foods shipped into Colorado, 1909. B. 153 :12, 1910.
Ceresa bubalus. See Buffalo tree-hopper.
Channels—
  concrete lined—
    measurement of frictional resistance. B. 194 :19, 1914.
  earth—
    measurement of frictional resistance. B. 194 :21, 1914.
  See also Flumes.
Chaparral distribution in Colorado. B. 224 :45, 1917.
Chemistry department, work. B. 6 :21, 1888 ; Spec. B. "A" :5, 1892.
Chemistry section, Report of,
  1888. David O'Brine. R. 1 :151.
  1889. David O'Brine. R. 2 :46.
  1890. David O'Brine. R. 3 :25.
  1891. David O'Brine. R. 4 :24.
  1892. David O'Brine. R. 5 :38.
  1893. W. P. Headden. R. 6 :56.
  1894. W. P. Headden. R. 7 :65.
  1895. W. P. Headden. R. 8 :118.
  1896. W. P. Headden. R. 9 :139.
Chemistry section, Report of. (Continued)—
  1897. W. P. Headden. R. 10 :52.
  1898. W. P. Headden. R. 11 :167.
  1899. W. P. Headden. R. 12 :41.
  1900. W. P. Headden. R. 13 :45.
  1901. W. P. Headden. R. 14 :19.
  1902. W. P. Headden. R. 15 :127.
  1903. W. P. Headden. R. 16 :21.
  1904. W. P. Headden. R. 17 :94.
  1905. W. P. Headden. R. 18 :37.
  1906. W. P. Headden. R. 19 :152.
  1907. W. P. Headden. R. 20 :20.
  1908. W. P. Headden. R. 21 :139.
  1909. W. P. Headden. R. 22 :25.
  1910. W. P. Headden. R. 23 :95.
  1911. W. P. Headden. R. 24 :13.
  1912. W. P. Headden. R. 25 :16.
  1913. W. P. Headden. R. 26 :10.
  1914. W. P. Headden. R. 27 :12.
  1915. W. P. Headden. R. 28 :9.
  1916. W. P. Headden. R. 29 :25.
  1917. W. P. Headden. R. 30 :23.
  1918. W. P. Headden. R. 31 :23.
Cherries—
  culture. B. 223 :39, 1917.
  fungous diseases of. B. 212 :26, 1915.
  insects injurious to. B. 71 :16, 1902 ; B. 114 :18, 1906 ; B. 210 :24. 1915.
  varieties. B. 17 :35, 1891 ; B. 223 : 46, 1917.
Cherry—
  aphis *(Myzus cerasi.)* B. 133 :42, 1908 ; B. 134 :14, 1908.
  slug. R. 15 :111, 1902 ; B. 210 :28, 1915.
  tree—
    wood parasite. B. 69 :11, 1902.
    pruning. B. 139 :8, 1909.
Chess *(Bromus secalinus.)* analysis. B. 12 :53, 1890.
Cheyenne County—
  agricultural notes. B. 59 :11, 1900.
Cheyenne Wells—
  meteorological observations. R. 15 : 195, 1902.
  precipitation. 1894-1911, B. 182 :43, 1912 ; 1894-1917, B. 245 :46, 1918.
  temperature. 1894-1911, B. 182 :44, 1912 ; 1894-1917, B. 245 :45, 1918.
Cheyenne Wells Sub-station report. See Plains Sub-station report.
Chicken—
  chigger. B. 185 :10, 1912.
  cholera. B. 186 :15, 1912.
  diseases. B. 185, 1912 ; B. 213 :12, 1915.
  flea. B. 185 :11, 1912.
  house—
    adobe. B. 174 :7, 1910.
    plan for B. 145 :12, 1909.

- Chicken (Continued)—
  - lice. B. 145 :13, 1909; B. 185 :5, 1912.
  - mites B. 185 :8, 1912.
- Chickens—
  - breeds of. B. 164 :5, 1910; B. 213 :9, 1915.
  - buildings for. B. 213 :5, 1915.
  - feeding. B. 164 :6, 1910; B. 213 :11, 1915.
  - incubation. B. 164 :9, 1910.
  - liver diseases. B. 185 :25, 1912.
  - marketing. B. 213 :13, 1915.
  - ovary diseases. B. 185 :22, 1912.
  - parasitic worms of. B. 185 :11, 1912.
  - white diarrhoea of. B. 185 :19, 1912.
- Chinch bug, false *(Nysius minutus.)* B. 6 :16, 1888; R. 14 :16, 1901.
- *Chionaspis*—
  - *furfurus.* See Scurfy scale.
  - *pinifoliae.* See Pine-leaf scale.
- Chlorin in ground water. B. 72 :18, 1902.
- Choke-cherry leaf-roller *(Cenopsis testulana.)* B. 94 :11, 1904.
- *Chorizafrotis auxilaris.* See Cutworm, army.
- *Chrysobothris femorata.* See Borer, flat-headed.
- *Cicuta occidentalis.* See Water hemlock.
- Cider vinegar. See Vinegar, cider.
- *Cippoletti module,* description. B. 13 : 25, 1890; B. 150 :27, 1909; B. 27 :30, 1894.
- *Claviceps purpura.* See Ergot.
- Clean milk and commercial starters as factors in butter making. Walter G. Sackett. B. 156, 1910.
- Clean, treated, and tested seed for Colorado. W. W. Robbins, H. E. Vasey, and G. F. Eggington. B. 238, 1918.
- Clear Creek—
  - seepage—
    - gains and losses 1900-1910. B. 180, pt. 1 :39, 1911; B. 180, pt. 3 :140, 1911.
    - measurement. 1900. R. 13 : 138, 1900.
  - water analysis. B. 82 :62, 1903.
    - measurement 1900-1910. B. 180, pt. 3 :44, 1911.
- Climate of Colorado. Temperature. 21 years record at Fort Collins. L. G. Carpenter and R. E. Trimble. B. 127, 1908.
- *Clisiocampa fragilis.* See Tent caterpillar.
- Clover—
  - aphis *(Aphis bakeri)*—
    - food plants. B. 133 :28, 1908.
    - life history. B. 133 :28, 1908.
  - mite *(Bryobia pratensis)*—
    - description and remedies, B. 47 :18, 1898; B. 114:8, 1906; B. 169 :10, 1910.
    - history. B. 152 :3, 1910.
    - notes. B. 210 :17, 1915.
    - remedies. B. 38 :38, 1897; B. 71 :8, 1902; B. 152 :6, 1910.
  - red *(Trifolium pratense.)* B. 2 :8, 1887; B. 68 :7, 1902.
  - sweet, aphis. See Sweet clover aphis.
- Clovers. B. 2 :7, 1888.
- *Coccotorus prunicida.* See Plum gouger.
- Cochran's milk test. B. 20 :4, 1892.
- COCKERELL, THEODORE DRU ALISON.
  - Bees of the genus *Nomada* found in Colorado. B. 94, 1904.
- Cocklebur poisoning. B. 211 :68, 1915.
- Codling moth—
  - description. R. 6 :52. 1893; R. 14 : 13, 1901; R. 16:18, 1903; B. 210 : 5, 1915.
  - remedies. P. B. 11, 1901; B. 64 :26, 1901; B. 71 :6, 1902; B. 114 :6, 1906; P. B. 42, 1907.
  - spraying experiments. P. B. 21, 1904; P. B. 44, 1907.
  - *(Carpocapsa pomonella)*—
    - bibliography. B. 15 :4, 1891.
    - description. B. 38 :39, 1897; R. 13 :123, 1900; R. 17 :91, 1904.
    - life history. B. 15 :4, 1891.
    - remedies. B. 6 :9, 1888; B. 15 :8, 1891; B. 38 :39, 1897; B. 47 : 4, 1898; R. 11 :161, 1898.
  - *(Cydia pomonella)*—
    - description. B. 119 :3, 1907.
    - spraying experiments. B. 119 :4, 1907.
- COGGINS, M. O.
  - Cantaloupes; from a luxury to a necessity. B. 108:11, 1906.
- Cold frames, construction. B. 199 :38, 1914; B. 221 :7, 1917.
- *Coleothrips trifasciata,* description. B. 24 :15,1893.
- College farm, Colorado Agricultural College—
  - costs. B. 203 :3, 1914.
- *Collops nigriceps.* B. 6 :18, 1888.
- Colorado—
  - birds. B. 37, 1897; B. 44, 1898; B. 56, 1900.

Colorado (Continued)—
- Carriage Horse Breeding Station—
  - information concerning. B. 166, 1910.
  - pedigree of stock at. B. 166 :9, 1910.
- climate of. B. 182 :1, 1912 ; B. 245:1, 1918.
  - in relation to agriculture. B. 224 :6, 1917.
- evergreen trees of. B. 130, 1908.
- Flora. B. 100, 1905.
- frost season, length. B. 224 :13, 1917 (map.)
- hog raising. B. 146, 1909.
- hogs, best breeds. B. 146 :5, 1909.
- native vegetation. B. 224 :30, 1917.
- potato. 1917. B. 243 :4, 1918.
  - industry. B. 175, 1910.
- precipitation (map.) B. 224 :21, 1917.
- pure seed law. B. 238 :32, 1918.
- swine feeding. B. 74, 1902.
- temperature in relation to agriculture (map.) B. 224 :6, 1917.
- unirrigated lands of eastern. B. 77, 1903.

Colorado Agricultural College farm—
- costs of. B. 203 :3, 1914.
- crop cost. B. 203 :9, 1914.
- horse labor cost. B. 203 :9, 1914.
- manual labor cost. B. 203 :8, 1914.
- service bureau expense. B. 203 :35, 1914.

Colorado climatology. Robert E. Trimble. B. 182, 1912 ; B. 245, 1918.

Colorado fodders ; an examination into their composition and comparative values. W. P. Headden. B. 124, 1907.

Colorado fodders ; a study of comparative values based on bulletin 124. W. P. Headden. B. 125, 1907.

Colorado grasses and their chemical analysis. J. Cassidy and David O'Brine. B. 12, 1890.

Colorado hays and fodders. W. P. Headden. B. 93, 1904.

Colorado *Hemiptera;* a preliminary list. C. P. Gillette. B. 31, 1895.

Colorado irrigation waters and their changes. W. P. Headden. B. 82, 1903.

Colorado *Lepidopera.* A few new species of *Deltocephalus* and *Athysanus* from Colorado. A list of original types, etc. in collection. C. P. Gillette. B. 43, 1898.

Colorado *Orthoptera,* an annotated list and some of the more imporant insects of 1903. C. P. Gillette. B. 94, 1904.

Colorado plants injurious to livestock. Geo. H. Glover and W. W. Robbins. B. 211, 1915.

Colorado potato industry. E. R. Bennett. B. 117, 1907.

Colorado raspberry industry. R. S. Herrick and E. R. Bennett. B. 171, 1910.

Colorado statue inch and some miner's inch measuring devices. V. M. Cone. B. 207, 1915.

Colorado sunshine. L. G. Carpenter. P. B. 2 in B. 64 ;6, 1901.

Colorado weeds. Chas. S. Crandall. B. 23, 1893.

Colorado's worst insect pests and their remedies. C. P. Gillette. B. 47, 1898.

Comb foundation. See Honey comb foundation.

Common insects of the garden. C. P. Gillette. B. 199 :40, 1914.

Comparative bacteriological study of the water supply of the city and county of Denver, Colorado. Walter G. Sackett. B. 225, 1917.

Concerning the duties of the State Board of Agriculture and the distribution of college seeds and plants. Frank J. Annis. B. 3, 1887.

Concerning subjects investigated by the Experiment Station. Walter J. Quick. Spec. B. "A", 1892.

Conclusions relative to the culture of sugar beets. W. P. Headden. P. B. 10, 1901.

Concrete—
- destruction by alkali. B. 132, 1908.
- fence post—
  - construction. B. 148 :3, 1909 ; B. 161 :3, 1910.
  - curing. B. 148 :16, 1909. B. 161 :8, 1910.
  - experiments. B. 148 :22, 1909 ; B. 161 :11, 1910.
  - moulds. B. 148 :9, 1909 ; B. 161 :15, 1910.
  - poured and tamped. B. 148 :8, 1909 ; B. 161 :4, 1910.
  - reinforcement. B. 148 :14, 1909 ; B. 161 :8, 1910.
  - wire fasteners. B. 148 :17, 1909 ; B. 161 :8, 1910.
- mixers, home made. B. 148 :6, 1909.
- Portland—
  - affected by alkali. B. 132 :5, 1908.

CONE, V. M.
- The Colorado statute inch and some miner's inch measuring devices. B. 207, 1915.

CONE, V. M. (continued)
  Dethridge meter. B. 215, 1915.
  divisors (For the measurement of irrigation water.) B. 228, 1917.
  Irrigation and drainage section report. R. 24-30, 1911-1917.
  —and KEZER, ALVIN.
  Irrigated agriculture in the San Luis Valley. B. 209, 1915.
  —and TRIMBLE, R. E. and JONES, P. S.
  Frictional resistance in artificial waterways. B. 194, 1914.

Conejos River—
  seepage—
    gains and losses, 1900-1903. B. 180, pt. 1 :44, 1911; B. 180, pt. 3 :145, 1911.
    measurement. R. 13 :139, 1900; B. 180, pt. 3:127, 1911.

Conotrachelus—
  leucophaetus. B. 6 :18, 1888.
  nenuphar. See Plum curculio.

Contract form for sugar beets. B. 42 : 54, 1898.

Co-operative experiment in tree planting. W. Paddock and B. O. Longyear. P. B. 22, 1905.

COOKE, WALTER W.
  Agricultural section, Report of, R. 6-12, 1893-1899.
  Barley. B. 40. 1897.
  Birds of Colorado. B. 37, 1897; B. 56, 1900.
  Cattle feeding in Colorado. B. 34, 1896.
  Farm notes; alfalfa, corn, potatoes, and sugar beets. B. 57, 1900.
  Further notes on the birds of Colorado. B. 44, 1898.
  Pasturing sheep on alfalfa. Raising early lambs. B. 52, 1899.
  Sheep feeding in Colorado. B. 32 1895.
  Sugar beets. B. 36, 1897.
  Sugar beets in Colorado in 1898. B. 51, 1899.
  —and HEADDEN, W. P.
  Sugar beets in Colorado in 1897. B. 42, 1898.
  —and WATROUS. F. L.
  Farm notes for 1893. B. 26, 1894.
  Farm notes for 1894 B. 30. 1894.

Copper sulphate injurious to trees. B. 118 :12, 1907.
Coprinus, varieties. B. 201 :27, 1914.
Cord grass *(Spartina cynosuroides.)* B. 12 :110, 1890.
Coreus tristis. See Squash bug.

Corn—
  culture. B. 26 :26, 1894.
  ear-worm *(Heliothis armigera.)* B. 199 :40, 1914.
  fodder—
    amid nitrogen. B. 124 :46, 1907.
    analysis. B. 124 :41, 1907.
    calorific value. B. 124 :46, 1907.
    coefficient of digestion. B. 124 :44, 1907.
    compared with alfalfa hay. B. 124 :49, 1907.
    digestibility. B. 93 :7, 1904; B. 93 :24, 1904.
    loss in drying. B. 30 :23, 1894.
    methoxyl in. B. 124 :45, 1907.
  for pigs. B. 74, 1902.
  fungous diseases of. B. 212 :25, 1915.
  notes. B. 2 :7, 1887; B. 30 :12, 1894; B. 172 :7, 1910.
  on plains lands. B. 214 :11, 1915.
  root-louse *(Tychea brevicornis.)* R. 15 :114, 1902.
  rootworm *(Diabrotica virgifera.)* B. 199 :40, 1914.
  seed, home grown compared to imported. B. 57 :17, 1900.
  shipped into Colorado B. 153 :11, 1910.
  silage. B. 30 :21, 1894; B. 57 :15, 1900.
    cost on college farm. B. 203 :17, 1914.
  smut control. B. 238 :29, 1918.
  sweet. See Sweet corn.
  varieties. B. 30 :12, 1894; B. 57 :20, 1900.
  versus alfalfa. B. 26 :4, 1894.
  worm. R. 6 :53, 1893.
  with sugar beet pulp and hay for steers. B. 102 :3, 1905.
  yield as affected by stalks in hill. B. 57 :24, 1900.

Corrosive sublimate, preparation. B. 212 :54, 1915.

Cost of Colorado roads. P. B. 29, 1907.

Cottonwood—
  borer *(Prionoxistus robiniae.)* B. 47:34, 1898; B. 210 :39, 1915.
  leaf beetle *(Plagiodera scripta.)* B. 6 :17, 1888.

Cottony maple scale. S. Arthur Johnson. B. 116, 1906.

Cottony maple scale. S. Arthur Johnson. P. B. 27, 1906.

Cottony maple scale. See Maple scale, cottony.

Corticum vagum. See Potato, *rhizoctonia*.

- Cost of beef production under semi-arid conditions. G. E. Morton. B. 189, 1913.
- COTTRELL, H. M.
  - Agricultural products shipped in Colorado in 1909. B. 153, 1909.
  - Animal husbandry section, Report of. R. 19, 1906.
  - Dairy work for plains settlers. P. B. 33, 1907; Same. B. 123 :8, 1907.
  - Dry land farming in eastern Colorado. B. 145, 1909.
  - Field peas in Colorado. P. B. 47, 1909.
  - Raising hogs in Colorado. B. 146, 1909.
  - Raising hogs on the plains. P. B. in B. 123 :18, 1907.
- Cow as an assistant; hints to plains settlers. J. E. Payne. P. B. 52, 1909.
- Cow cockle *(Saponaria vaccaria)*—
  - description. B. 23 :8, 1893.
  - notes. B. 211 :28, 1915.
- Cowbane. See Water Hemlock.
- Cowdry—
  - meteorological observations. R. 15 : 198, 1902.
  - precipitation 1890-1911. B. 182 :49, 1912; B. 245 :53, 1918.
  - temperature 1893-1911. B. 182 :49, 1912; B. 245 :53, 1918.
- Cowpea *(Vigna catjung)*—
  - notes. B. 68 :7, 1902.
  - on plains lands. B. 214 :24, 1915.
- Cows—
  - feeding experiments. B. 20 :12, 1892.
  - sugar-beet pulp for. B. 73 :11, 1902 (tables.)
  - tuberculosis in. B. 66 :10, 1901.
- Crab—
  - apples. B. 17 :34, 1891.
  - grass *(Panicum sanguinale.)* B. 12 : 35, 1890.
- CRANDALL, CHARLES S.
  - Blight and other plant diseases. B. 41, 1898.
  - Botanical and horticultural section, Report of. R. 3-12, 1890-1899.
  - Colorado weeds. B. 23, 1893.
  - Grass Station report. R. 3-4, 1890-1891.
  - Notes on plum culture. B. 50, 1898.
  - Preliminary report on the fruit interests of the state. B. 17, 1891.
  - Russian thistle. B. 38, 1894.
  - —and HUFFINGTON, M. J.
  - Garden notes for 1893. B. 26 :11, 1894.
  - —and POTTER, C. H.
  - Strawberries. B. 53, 1900.
- CRAIN, LD
  - Engineering division report. R. 31, 1918.
- Cream—
  - care of. B. 202 :9, 1914.
  - churning. B. 163 :9, 1910.
  - pasteurized for butter. B. 156 :13, 1910.
  - ripening for butter. B. 156 :13, 1910; B. 163 :8, 1910.
  - sampling and receiving. B. 202 :13, 1914.
  - separator. B. 163 :7, 1900.
  - station—
    - equipment. B. 202 :22, 1914.
    - problems. B. 202 :21, 1914.
  - testing. B. 202 :15, 1914.
- Crickets—
  - mountain *(Anabrus simplex.)* R. 17 : 92, 1904.
  - western—
    - control of. B. 101 :7, 1905.
    - habits. B. 101 :5, 1905.
    - history. B. 101 :3, 1905.
    - migratory habits. B. 101 :11, 1905.
- Crops for unirrigated lands. J. E. Payne. P. B. 18, 1903; B. 123 :6, 1907.
- CROSMAN, RALPH L.
  - Publications, Editor of, Report of. R. 30-31, 1917-1918.
- CROWLEY, W. FRANK.
  - Arkansas Valley Experiment Station report. R. 10, 1897.
- Crown gall—
  - description. B. 86 :3, 1903.
  - notes. B. 118 :11, 1907.
  - remedies. B. 86 :7, 1903.
- Crown gall. Wendell Paddock. B. 86, 1903.
- Cucumber—
  - beetle, striped *(Diabrotica vittata)*—
    - description and remedies. B. 47 :39, 1898; B. 62 :16, 1901; B. 199 :45. 1914.
  - fungous diseases of. B. 212 :27, 1915.
  - notes. B. 172 :9, 1910; B. 199 :15, 1914; B. 241 :19, 1918.
  - wilt. B. 138 :22, 1909; B. 212 :27, 1915.
- Cultural methods for sugar beets. Progress bulletin. W. H. Olin. B. 109, 1906.

- Currant—
  - borer, impôrted—
    - *(Sesia tipuliformis.)* B. 19 :21, 1892; B. 47:27, 1898; B. 114 : 23, 1906.
      - remedies. B. 71 :18, 1902.
    - *(Aegeria tipuliformis.)* B. 6 :12, 1888.
  - cane borer B. 210 :34, 1915.
  - cane disease *(Nectria cinnabarina.)* B. 69 :13, 1902; B. 212 :28, 1915.
  - fruit—
    - maggot *(Epochra canadensis.)* B. 114 :24, 1906.
    - *worm (zophodia bella.)* B. 114 : 25, 1906.
  - measuring worm *(Eufitchia ribearia.)* B. 6:8, 1888.
  - plant louse. B. 210 :33, 1915.
  - saw-fly *(Pristiphora grossulariae)*—
    - description and remedies. B. 47 :27, 1898; B. 71 :18, 1902; B. 114, 23, 1906.
    - notes. B. 210 :33, 1915.
  - span-worm *(Thamnonoma 4-linearia & T. flavicaria.)*
    - description and remedies. B. 19 :23, 1892; B. 47 :27, 1898.
- Currants—
  - culture. B. 195 :14, 1914.
  - fungous diseases of. B. 212 :28, 1915.
  - insects injurious to. B. 71 :18, 1902; B. 114 :23, 1906; B. 210 :31, 1915.
  - varieties. B. 17 :35, 1891; B. 60 :6, 1900; B. 223 :46, 1917.
- *Cuscuta.* See Dodder.
- Cutworm—
  - alfalfa. R. 13 :127, 1900.
  - army *(Chorizafrotis auxilaria)* B. 94 :6, 1904.
- Cutworms—
  - description. B. 98 :17, 1905.
  - notes. B. 199 :46, 1914.
  - remedies. B. 47 :47, 1898. B. 98 :21, 1905.
- Cutworms. S. Arthur Johnson. B. 98, 1905.
- *Cydia pomonella* See Codling moth.
- *Cyllene robiniae* See Locust borer.
- *Cyrtonema stabulans* See Squash root-maggot.
- *Dactylis glomerata* See Orchard grass.
- Dairy—
  - building. B. 163 :3, 1910.
  - herd, testing. B. 202 :3, 1914.
  - inspection. B. 202 :29, 1914.
  - products shipped into Colorado. B. 153 :7, 1910.
- Dairy work for plains settlers. H. M. Cottrell. P. B. 33, 1907; B. 123 :8, 1907.
- Dairying—
  - cleanliness in. B. 163 :4, 1910.
  - history in eastern Colorado. B. 88 :19, 1904.
  - in eastern Colorado. B. 88, 1904; B. 145 :7, 1909.
- Dairying on the plains. J. E. Payne. B. 88, 1904.
- Dandelions—
  - as a field weed. B. 236 :31, 1918.
  - digging. B. 236 :25, 1918.
  - eradication experiments, 1909, 1910, 1915, 1916. B. 236 :13, 1918.
  - life history. B. 236 :4, 1918.
  - natural enemies. B. 236 :11, 1918.
  - spraying. B. 236 :19, 1918.
- Dandelions in Colorado. B. O. Longyear. B. 236, 1918.
- DANIELSON, ANDREW H.
  - Agricultural section, Report of. R. 15-16, 1902-1903.
  - Fertilizer experiments with sugar beets. B. 115, 1906.
- *Danthonia*—
  - *californica.* B. 12 :87, 1890.
  - *intermedia* B. 12 :87, 1890.
- Death camas *(zygadenus venenosus)*—
  - description. B. 211 :22, 1915.
  - poisoning—
    - description. B. 113 :19, 1906.
    - treatment. B. 113 :20, 1906; B. 211 :25, 1915.
- *Delphinium.* See Larkspur.
- Delta County fruit investigations. L. F. Paull. R. 20 :33, 1907.
- *Deltocephalus parvulus* B. 43 :23, 1898.
- Denitrification, in soils. B. 196 :21, 1914.
- Denver—
  - precipitation. 1870-1911, B. 182 :52, 1912; 1870-1917, B. 245 :56, 1918.
  - shade trees of. B. 96 :3, 1905.
  - water supply—
    - bacteriological study of. B. 225 :9, 1917.
    - comparative study of. B. 225 :3, 1917.
    - ordinance for protection of. B. 225 :7, 1917.
    - sketch of. B. 225 :5, 1917.
    - source. B. 225 :4, 1917.
- *Deschampsia*—
  - *caespitosa.* See Hair grass.
  - *danthonioides.* B. 12 :71, 1890.
  - *flexuosa.* B. 12 :71, 1890.

Destruction of concrete by alkali. W. P. Headden. B. 132, 1908.

Deterioration of manures under semi-arid conditions. W. P. Headden and Earl Douglass. B. 168, 1910.

Deterioration in the quality of sugar beets due to nitrates formed in the soil. W. P. Headden. B. 183, 1912.

Dethridge meter. V. M. Cone. B. 215, 1915.

Development of the Rocky Ford cantaloupe industry. P. K. Blinn. B. 108, 1906.

Dewberries—
- culture. B. 136, 1909; B. 195 :9, 1914.
- insects injurious to. B. 210 :35, 1915.
- packing. B. 136, 1909.
- varieties. B. 60 :10, 1900.

Dewberry growing. O. B. Whipple. B. 136, 1909.

Deyeuxia—
- *canadensis.* See Blue joint.
- *lapponica.* B. 12 :47, 1890.
- *stricta.* B. 12 :47, 1890.
- *sylvatica.* B. 12 :44, 1890.
- *vittata.* See Cucumber beetle, striped.

Digestion experiments with some Colorado hays and fodders. W. P. Headden. B. 93, 1904.

Diplachne fascicularis. B. 12 :109, 1890.

Distichlis maritima See Salt grass.

Distribution of water; Power and duties of irrigation officials in Colorado. H. N. Haynes. B. 67, 1901.

Ditches, loss by seepage. B. 48, 1898.

Divide Experiment Station—
- meteorological observations. R. 4 :95, 1891.
- report,
  - 1891. F. Breninger. R. 4 :115.
  - 1892. F. Breninger. R. 5 :61.
  - 1893. J. H. McClelland. R. 6 :58.
  - 1894. J. H. McClelland. R. 7 :74.
  - 1895. J. H. McClelland. R. 8 :123

Divisors—
- description. B. 13 :6, 1890; B. 27 :8, 1894; B. 150 :13, 1909; B. 228:3, 1917.
- tests. B. 228 :7, 1917.

Divisors. (For the measurement of irrigation water.) V. M. Cone. B. 228, 1917.

Dodder *(Cuscuta)*—
- alfalfa. B. 8 :6, 1889.
  - eradication. B. 248 :10, 1918.

Dodder *(Cuscuta)*—(Continued)—
- Alfalfa (Continued)—
  - in Colorado. B. 248 :5, 1918.
  - life history. B. 248 :6, 1918.
  - means of spreading. B. 248 :8, 1918.
  - varieties. B. 248 :9, 1918.

Dogbane *(Apocynum androsaemifolium.)* B. 211 :57, 1915.

Doryphora 10-lineata. See Potato beetle.

DOUGLASS, EARL See Headden, William P. jt. author. B. 168, 1910.

Drainage water, composition. B. 82 :48, 1903.

Dry Creek, water measurement. B. 180, pt. 3 :43. 1911.

Dry farming—
- alfalfa for. B. 90, 1904; B. 214 :7, 1915.
- area in Colorado. B. 227 :3, 1917.
- corn for. B. 214 :11, 1915.
- crops for. B. 103 :12, 1905; P. B. 18, 1903; B. 123 :6, 1907; B. 145 : 22, 1909; B. 227 :16, 1917.
- Dairying on. B. 145 :7, 1909.
- fruit trees for. B. 173, 1910.
- garden. B. 145 :14, 1909.
- in eastern Colorado. B. 77, 1903; P. B. 18, 1903; B. 123 :6, 1907; B. 145, 1909.
- management. B. 227 :16, 1917.
- moisture conservation. B. 227 :8, 1917; B. 145 :15, 1909.
- millets for. B. 214 :19, 1915.
- plowing. B. 103 :3, 1905.
- poultry raising. B. 145 :11, 1909.
- principles of. B. 103 :3, 1905.
- seed quantities for. B. 103 :7, 1905; B. 227 :15, 1917.
- seed selection for. B. 103 :7, 1905.
- soils treatment. B. 227 :7, 1917.
- sorghums for. B. 214 :13, 1915.
- sweet clover for. B. 214 :20, 1915.
- tillage in. B. 103 :3, 1905.

Dry farming in Colorado. Alvin Kezer. B. 227, 1917.

Dry land farming in eastern Colorado. (Information bulletin.) H. M. Cottrell. B. 145, 1909.

Dry land specialist report. J. W. Adams. R. 29 :16, 1916.

Dry land station report. See Plains Substation report.

DUNCAN, CHARLES A.
- San Luis Valley Experiment Station report. B. 7-9, 1894-1896.

Durango—
- precipitation, 1886-1911, B. 182 :55 1912; 1886-1917, B. 245 :60, 1918.

DVORACHEK, H. E.
- Silos and silage in Colorado. B. 200, 1914.

Early cantaloupes. P. K. Blinn. B. 95, 1904.

Early market conditions of cantaloupes on the New York market. Lyons Brothers Company. B. 108 :13, 1906.

Eatonia obtusata. B. 12 :106, 1890.

Eddy, New Mexico. Beet sugar factory. B. 42 :48, 1898.

Editor of publications. See Publications, Editor of, Report of.

Egg plant—
  blight. B. 138 :19, 1909.
  notes. B. 26 :17, 1894 ; B. 172 :10, 1910 ; B. 241 :20, 1918.
  varieties. B. 26 :17, 1894.

EGGINGTON, G. E. See Robbins, W. W. jt. author. B. 238, 1918 ; B. 248, 1918.

Eggs shipped into Colorado. B. 153 :9, 1910.

Eight-spotted forester *(Alypia octomaculata)*—
  description and remedies. B. 6 :12, 1888 ; B. 47 :25, 1898 ; B. 71 :17, 1902 ; B. 114:22, 1906.
  notes. R. 13 :124, 1900.

ELLIS, ALSTON—
  Experiment Station report. R. 6-11, 1893-1898.

Elm—
  aphis *(Schizoneura americana.)* R. 10 :59, 1897.
  leaf caterpillar *(Vanessa antiopa.)* B. 6 :17, 1888.
  leaf cluster gall *(Schizoneura americana.)* B. 47 :35, 1898.
  scale. B. 210 :37, 1915.

Elymus—
  analysis. B. 12 :61. 1890.
  americanus. B. 12 :57, 1890.
  canadensis B. 12 :58, 1890.
  condensatus. See Rye grass, giant.
  sibericus. B. 12 :54, 1890.
  sitanion B. 12 :62, 1890.

Emmer culture in the San Luis Valley. B. 209 : 28, 1915.

Engineer (State)—
  powers and duties. B. 67 :25, 1901.

Engineering division, Report of, 1918. LD Crain. R. 31 :26, 1918.

Entomological department work. Spec. B. "A" :7, 1892.

Entomological section, Report of,
  1891. C. P. Gillette. R. 4 :98.
  1892. C. P. Gillette. R. 5 :34.
  1893. C. P. Gillette. R. 6 :51.
  1894. C. P. Gillette. R. 7 :58.
  1895. C. P. Gillette. R. 8 :115.
  1896. C. P. Gillette. R. 9 :143.

Entomological section, Report of (Continued)—
  1897. C. P. Gillette. R. 10 :55.
  1898. C. P. Gillette. R. 11 :161.
  1899. C. P. Gillette. R. 12 :37.
  1900. C. P. Gillette. R. 13 :123.
  1901. C. P. Gillette. R. 14 :13.
  1902. C. P. Gillette. R. 15 :103.
  1903. C. P. Gillette. R. 16 :18.
  1904. C. P. Gillette. R. 17 :91.
  1905. C. P. Gillette. R. 18 :41.
  1906. C. P. Gillette. R. 19 :142.
  1907. C. P. Gillette. R. 20 :24.
  1908. C. P. Gillette. R. 21 :133.
  1909. C. P. Gillette. R. 22 :28.
  1910. C. P. Gillette. R. 23 :98.
  1911. C. P. Gillette. R. 24 :28.
  1912. C. P. Gillette. R. 25 :30.
  1913. C. P. Gillette. R. 26 :9,
  1914. C. P. Gillette. R. 27 :11.
  1915. C. P. Gillette. R. 28 :14.
  1916. C. P. Gillette. R. 29 :27.
  1917. C. P. Gillette. R. 30 :24.
  1918. C. P. Gillette. R. 31 :25.

Entomologist, field, Report of.
  1906. E. P. Taylor. R. 19 :147.
  1907. E. P. Taylor. R. 20 :25.
  1908. G. P. Weldon. R. 21 :136.
  1909. G. P. Weldon. R. 22 :31.
  1910. G. P. Weldon. R. 23 :100.
  1911. G. P. Weldon. R. 24 :32.

Ephestia kuhniella. See Flour moth, Mediterranean.

Epilachna corrupta. See Bean beetle, spotted.

Epitrix cucumeris. See Potato flea beetle.

Epochra canadensis. See Currant fruit maggot ; Gooseberry fruit maggot.

Equisetum poisoning in animals. B. 211 :15, 1915.

Eragrostis—
  poaeiodes. B. 12 :78, 1890.
  purshii. B. 12 :78, 1890.

Ergot *(Claviceps purpura.)* B. 211 :10, 1915.

Ergotism. B. 211 :11, 1915.

Eriocampa cerasi. See Pear slug.

Eriocampoides limacina. See Pear slug.

Estes Park—
  meteorological observations. 1902, R. 15 :196, 1902 ; 1891-1911, B. 182 :48, 1912.
  precipitation. 1891-1917, B. 245 : 52, 1918.
  temperature. 1892-1911, B. 182 :46. 1912 ; 1892-1917, B. 245 :49, 1918.

Eufitchia ribearia. See Currant measuring worm.

Euphorbia marginata. See Snow-on-the-mountain.

European—
  cabbage caterpillar. See Cabbage butterfly, imported.
  grain aphis. See Grain aphis, European.
Eurotia lanata. B. 12 :128, 1890.
Eurycreon rantalis. See Garden webworm.
Evaporation—
  affected by—
    elevation. B. 45 :27, 1898.
    temperature. B. 45 :14, 1898.
  Fort Collins. 1889, R. 2 :68, 1889; 1890-1891, R. 4 :50, 1891; B. 49 : 64, 1898.
  from ditches. B. 48 :6, 1898.
  from reservoirs. B. 45, 1898.
  See also Meteorological observations.
Evaporometer. B. 49 :14, 1898.
Evergreen trees of Colorado. B. O. Longyear. B. 130, 1908.
Evergreens—
  description. B. 130 :4, 1908.
  from seeds. B. 130, 1908.
  species, illustrated. B. 130 :13, 1908.
  transplanting. B. 130 :6, 1908.
Experiment Station, history and organization. R. 1 :5, 1888.
Extension superintendent, Report of. C. H. Hinman. R. 23 :107, 1910.
Extraction of beeswax. F. C. Alford. B. 129, 1908.
Fall web-worm *(Hyphantria cunea)*—
  description and remedies. B. 47 :8, 1898; B. 71 :7, 1902; B. 114 :7, 1906.
  notes. B. 210 :14, 1915.
Farm butter making. H. M. Bainer. B. 163. 1910.
Farm costs on the Colorado Agricultural College farm. Alvin Keyser. B. 203, 1914.
Farm machinery. See Agricultural machinery.
Farm machinery and dairying report. H. M. Bainer. B. 22 :62, 1909.
Farm manager report. Alvin Keyser. R. 23 :110, 1910.
Farm notes, alfalfa, corn, potatoes, and sugar beets. W. W. Cooke. B. 57, 1900.
Farm notes for 1893. W. W. Cooke and F. L. Watrous. B. 26, 1894.
Farm notes for 1894. W. W. Cooke and F. L. Watrous. B. 30, 1894.
Feeding beet pulp and sugar beets to cows. The feeding value of beet pulp. B. C. Buffum and C. J. Griffith. B. 73, 1902.
Feeding beet pulp to lambs. H. H. Griffin. B. 76, 1902.
Feeding experiments with lambs, 1908/9, 1909/10, 1910/11. Alfalfa meal for feeding lambs. Ration with lambs. Loss caused by dogs among lambs. G. E. Morton. B. 187, 1913.
Feeding steers on sugar beet pulp, alfalfa hay, and farm grains. W. L. Carlyle, C. J. Griffith, and A. J. Meyer. B. 97, 1905.
Feeding steers on sugar beet pulp, alfalfa hay, and ground corn. W. L. Carlyle and C. J. Griffitn. B. 102, 1905.
Feeding stuffs—
  comparative value. B. 34 :21, 1896; B. 40 :20, 1897.
Feeding value of beet pulp. Feeding beet pulp and sugar beets to cows. B. C. Buffum and C. J. Griffin. B. 73, 1902.
Feldspar—
  results in soil due to. B. 65 :28, 1901.
  source of mineral matter in water. B. 82 :8, 1903.
Fence posts, concrete—
  alkali effect on. B. 161 :13, 1910.
  construction. B. 148 :3, 1909.
  curing. B. 148 :16, 1909; B. 161 :8, 1910.
  experiments. B. 148 :22, 1909; B. 161:11, 1910.
  moulds. B. 148 :9, 1909; B. 161 :5, 1910.
  poured and tamped. B. 148 :8, 1909; B. 161 :4, 1910.
  reinforcement. B. 148 :14, 1909; B. 161 :8, 1910.
  wire fasteners. B. 148 :17, 1909; B. 161 :8, 1910.
Fertilizer—
  effect on wheat. B. 208 :35, 1915; B. 217 :21, 1916.
  experiments with sugar beets. B. 115 :3, 1906.
Fertilizer experiments with sugar beets. A. H. Danielson. B. 115, 1906.
Fescue grass *(Festuca elatior)*—
  notes. B. 68 :4, 1902; B. 12 :39, 1890.
Festuca—
  elatior. See Fescue grass.
  kingii. B. 12 :36, 1890.

- Festuca (Continued)—
  - *microstachys.* B. 12 :35, 1890.
  - *ovina* var. *brevifolia* B. 12 :36, 1890.
  - *scabrella.* B. 12 :137, 1890.
  - *tenella.* B. 12 :35, 1890.
- A few common insect pests. C. P. Gillette. B. 24, 1893.
- A few insect enemies of the orchard. C. P. Gillette. B. 38, 1897.
- A few new species of *Deltocephalus* and *Athysanus* from Colorado. C. P. Gillette. B. 43 :23, 1898.
- A few orchard plant lice. C. P. Gillette and E. P. Taylor. B. 133, 1908.
- Field notes from trips in eastern Colorado. J. E. Payne. B. 59. 1900.
- Field peas in Colorado. H. M Cottrell. P. B. 47, 1909.
- Fir, red. See Firs, Douglass.
- Fire blight. See Pear blight.
- Firs—
  - Alpine. See Firs, balsam.
  - balsam. B. 130 :29, 1908.
  - Douglass *(Pseudotsuga mucronata)* B. 130 :27, 1908.
  - varieties. B. 130 :28, 1908.
  - white. B. 130 :29, 1908.
- Fitch, C. L.
  - Potato specialist report. R. 24-25, 1911-1912.
  - Productiveness and degeneracy of the Irish potato. B. 176, 1910.
  - Studies of health in potatoes. B. 216 ; 1915.
  - —and Bennett, E. R.
  - Potato industry in Colorado. B. 175, 1910.
- Fixation of nitrogen in Colorado soils. The distribution of the nitrates and their relation to alkalis. W. P. Headden. B. 186, 1913.
- Fixation of nitrogen in some Colorado soils. W. P. Headden. B. 155, 1910.
- Fixation of nitrogen in some Colorado soils. (A further study.) W. P. Headden. B. 178, 1911.
- Flax—
  - culture. P. B. 55, 1912 ; P. B. 58, 1915.
    - San Luis Valley. B. 209 :30, 1915.
  - fungous diseases of. B. 212 :29, 1915.
  - notes. B. 2 :5, 1887.
  - seed treatment. P. B. 57, 1913.
  - soil preparation. P. B. 57, 1913.
  - wilt. B. 212 :29, 1915. B. 238 :29, 1918.
- Flax growing. Alvin Keyser. P. B. 55, 1912 ; P. B. 58, 1915.
- Flax seeding. Alvin Keyser. P. B. 57, 1913.
- Flea beetle—
  - notes. B. 47 :40, 1898 ; B. 62 :16, 1901 : B. 199 :46, 1914.
  - striped *(Systena taeniata)*—
    - description and remedies. B. 24 :10, 1893.
- Flora of Colorado. P. A. Rydberg. B. 100, 1905.
- Flour—
  - baking tests. B. 244 :11, 1918.
  - composition. B. 244 :11, 1918.
  - milling results. B. 244 :11, 1918.
  - moth, Mediterranean *(Ephestiakuhniella.)* B. 47 :50, 1898.
  - shipped into Colorado. B. 153 :10, 1910.
- Flumes—
  - metallic—
    - measurement of frictional resistance. B. 194 :5, 1914.
  - rating. B. 150 :36, 1909.
  - timber—
    - measurement of frictional resistance. B. 194 :5, 1914.
  - *See also* Channels.
- Fodders, Colorado. B. 124, 1907 ; B. 125 :3, 1907.
- Foot and mouth disease. B. 137 :10, 1909.
- Forage crops for the Colorado plains. Alvin Kezer. B. 214, 1915.
- Forage plants, notes. B. 30 :10, 1894.
- Forcing strawberries. Florence Kinnison. B. 222, 1917.
- Forestry section, Report of,
  - 1906. B. O. Longyear. R. 19 :138.
  - 1907. B. O. Longyear. R. 20 :28.
  - 1915. B. O. Longyear. R. 28 :28.
  - 1916. B. O. Longyear. R. 29 :27.
  - 1917. B. O. Longyear. R. 30 :26.
  - 1918. B. O. Longyear. R. 31 :27.
- Forests—
  - effect on streams flow. B. 55, 1901.
- Forests and snow. L. G. Carpenter. B. 55, 1901.
- Formalin—
  - preparation. B. 212 :53, 1915.
  - seed grain treatment. P. B. 24, 1906.
- Formalin treatment of seed grain for smut. W. H. Olin and F. Knorr. P. B. 24, 1906.
- Fort Collins, Colorado—
  - barometric reading, 1887-1911. B. 182 :36, 1912.

Fort Collins, Colorado (Continued)—
  evaporation, 1887-1911. B. 182 :39, 1912.
  precipitation, 1892-1911. B. 182 :37, 1912.
  stormy days, 1887-1911. B. 182 :38, 1912.
  temperature, 1887-1906, B. 127, 1908 ; 1887-1911, B. 182 :18, 1912.
  wind, 1888-1911. B. 182 :38, 1912.
Fort Morgan canal, seepage loss. B. 48 :15, 1898.
Foxtail—
  grass. See Squirrel-tail grass.
  pines. See Pines, foxtail.
FRANCIS, JAMES B.
  Investigations on the flow of water. B. 27:24, 1894.
  Summary of experiment on weirs. B. 150 :25, 1909.
Franseria discolor, description. B. 23 :10, 1893.
Frictional resistance in artificial waterways. V. M. Cone, R. E. Trimble and P. S. Jones. B 194, 1914.
Frost—
  fruit tree protection from. B. 80, 1903.
  season length (map) B. 224 :13, 1917.
Fruit—
  grower's association, list. B. 122 :9, 1907.
    Northern district. B. 122 :8, 1907.
    Western Slope district. B. 122 :3 ; 1907.
  growing—
    Northern district. B. 17 :5, 1891.
    Southern district. B. 17 :12, 1891.
    Western district. B. 17 :22, 1891.
  maggot. B. 210 :31, 1915.
  marketing, Grand Valley. B. 223 : 15, 1917.
  trees—
    frost injury. B. 41 :15, 1898 ; B. 212 :47, 1915.
    grafting. B. 147 :3, 1909.
    injured by arsenic. B. 131, 1908 ; B. 157, 1910.
    leaf roller. B. 210 :8, 1915.
      Archips argyrospila. B. 114 :7, 1906.
      Cacoecia argyrospila. B. 19 :3, 1892 ; B. 47 :5, 1898 ; B. 71 :6, 1902, remedies, B. 94 :9, 1904.
Fruit (Continued)—
  Trees (Continued)—
    lime's effect on. B. 157 :35, 1910.
    on dry land. B. 173, 1910.
    pruning. B. 106 :3, 1905 ; B. 139, 1909.
    spraying costs. B. 223 :13, 1917.
    spring frost injuries. B. 170 : 17, 1910.
    sun scald of. B. 212 :47, 1915.
    top-working. B. 147 :3, 1909.
    winter injury. B. 170 :12, 1910.
  survey—
    Mesa County. B. 223 :3, 1917.
    methods of. B. 223 :5, 1917.
  worm, notes. B. 210 :31, 1915.
Fruit growers association. W. Paddock. B. 122, 1907.
Fruit interests of the state, Report of. C. S. Crandall. B. 17, 1891.
Fruit raising. Sugar beets. Irish potatoes. F. L. Watrous. B. 21, 1892.
Fruit survey of Mesa County. E. P. Sandsten. T. F. Limbocker, and R. A. McGinty. B. 223, 1917.
Fruits—
  dried, shipped into Colorado. B. 153 : 20, 1910.
  orchard protection. B. 80, 1903.
  shipped into Colorado. B. 153 :16, 1910.
Fungi—
  edible. B. 201 :3, 1914.
  poisoning in animals. B. 211 :7, 1915.
Fungous diseases of Colorado crop plants. W. W. Robbins and Otto A. Reinking. B. 212, 1915.
Furfurol—
  in alfalfa. B. 124 :16, 1907.
  in native hay. B. 124 :34, 1907.
  in saltbush. B. 124 :72, 1907.
  in timothy. B. 124 :28, 1907.
Further notes on the birds of Colorado. W. W. Cooke. B. 44, 1898.
Fusarium. See Aster wilt.
Garden—
  on plains lands. P. B. 50, 1910.
  vegetable. See Vegetable garden.
  webworm—
    Loxostege cerearlis. R. 6 :53, 1893.
    Eurycreon rantalis. B. 6 :13, 1888.
Garden notes for 1893. C. S. Crandall and M. J. Huffington. B. 26 :11, 1894.
Garden notes for 1910. E. R. Bennett. B. 172, 1910.

GARDNER, J. J.
Harvesting and storing vegetables for home use. B. 232, 1917.
Garnett, Costilla county, Colorado—
precipitation. 1892-1911. B. 182: 54, 1912; 1892-1917, B. 245:59, 1918.
Gasoline as an insecticide. B. 71:28, 1902; B. 114:37, 1906; B. 210:47, 1915.
Gaura, small flowered. B. 23:8, 1893.
GILLETTE, CLARENCE PRESTON.
Apiary experiments. B. 54, 1900.
Beet army-worm. P. B. 3, 1900; Same. B. 64:10, 1901.
Beet web-worm. The beet army-worm. B. 98, 1905.
Colorado *Lepidoptera*. A few new species of *Deltocephalus* and *Athysanus* from Colorado. A list of original types, etc. in collection. B. 43, 1898.
Colorado's worst insect pests and their remedies. B. 47, 1898.
Common insects of the garden. B. 199, 1914.
Entomological section, Report of, R. 4-31, 1911-1918.
Experiment Station, Report of. R. 23-31, 1910-1918.
A few common insect pests. B. 24, 1893.
Grasshoppers, their habits and remedies. P. B. 19, 1903.
Grasshoppers upon the plains. P. B. 38, 1907; Same. B. 123:17, 1907.
Green aphis and the wooly aphis of the apple. P. B. 31, 1907.
How to fight the codling moth. P. B. 11, 1901; Same. B. 64:26, 1901.
Insects and insecticides. B. 71, 1902; B. 114, 1906.
Locust borer *(Cyllene robiniae* Forst.) P. B. 32, 1907.
Observations on injurious insects. B. 19, 1892.
San Jose scale. P. B. 48, 1909.
Sheep scab. A few insect enemies of the orchard. B. 38, 1897.
Report of the entomologist. Some of the more important insects of 1903 and an annotated list of Colorado *Orthoptera*. B. 94, 1904.
Spraying for codling moth, some important points to be considered. P. B. 44, 1907.
Spraying for plant lice and codling moth. P. B. 21, 1904.
Spring grain-louse. P. B. 45, 1907.
Sugar beet caterpillar. P. B. in B. 64:4, 1901.
GILLETTE, CLARENCE PRESTON (Continued)—
Two insect pests; the codling moth and the grape-vine leaf-hopper. B. 15, 1891.
Western cricket. Life history and remedies. B. 101, 1905.
—and BAKER, CARL F.
A preliminary list of the *Hemiptera* of Colorado. B. 31, 1895.
—and LIST, GEORGE M.
Insects and insecticides (Rev. edition of B. 114.) B. 210, 1915.
—and TAYLOR, E. P.
A few orchard plant lice. B. 133, 1908.
Orchard plant lice and their remedies. B. 134, 1908.
—and WELDON, GEORGE P.
Two plant lice of the peach. B. 169, 1910.
Glanders. B. 137:9, 1909.
Gleneyere, Colorado—
meteorological observation. R. 15: 197, 1902.
GLOVER, GEORGE H.
Hog cholera control. B. 197, 1914.
Larkspur and other poisonous plants. B. 113, 1906.
Relation of bovine to human tuberculosis. B. 66, 1901.
Veterinary section, Report of. R. 17-31, 1904-1918.
—and BARNES, C. L. and KAUPP, B. F. Some animal diseases. B. 137, 1909.
—and KAUPP, B. F.
Rabies. B. 162, 1910.
—and NEWSOM, I. E.
Brisket disease (Dropsy of high altitudes.) B. 204, 1915.
Brisket diseases (Bul. 204 rev. and abbreviated.) B. 229, 1917.
—and NEWSOM, I. E. and ROBBINS, W. W.
New poisonous weed, the whorled milkweed. B. 246, 1918.
—and ROBBINS, W. W.
Colorado plants injurious to livestock. B. 211, 1915.
Glyceria—
aquatica. B. 12:103, 1890.
distans. B. 12:103, 1890.
nervata. B. 12:100, 1890.
pauciflora. B. 12:100, 1890.
Glycine hispida. See Soy bean.
Good roads. See Roads, construction.
Gooseberries—
culture. B. 195:16, 1914.
fungous diseases of. B. 212:30, 1915.

Gooseberries (Continued)—
  - insects injurious to. B. 210 :31, 1915.
  - varieties. B. 17 :36, 1891; B. 60 :4, 1900; B. 223:47, 1917.

Gooseberry—
  - fruit fly *(Trypeta canadensis.)* B. 19 :18, 1892.
  - fruit maggot *(Epochra canadensis.)* B. 114 :24, 1906.
  - fruit worm *(Zophodia bella.)* B. 114 :25, 1906.
  - span-worm *(Thamnonoma 4-linearia & T. Flavicaria.)* B. 19 :23, 1892; B. 47 :27, 1898.

Grafting methods. B. 147 :6, 1909.

Grain—
  - aphis, European *(Aphis (Siphocoryne) avenae.)* B. 133 :30, 1908.
  - bug *(Pentama sayi)* injuries. B. 94 :3, 1904.
  - louse *(Toxoptera graminum.)* P. B. 45, 1907.
  - seed treatment of. P. B. 49, 1909.
  - shipped into Colorado. B. 153 :10, 1910.

Grains—
  - food taken from soil by. B. 142 :8, 1909.
  - for pigs. B. 75 :19, 1902.

Grains, grasses, and vegetables. A. E. Blount. B. 2, 1887.

Grama grass—
  - *(Bouteloua hirsuta.)* B. 12 :121, 1890.
  - *(Bouteloua oligostachya.)* B. 12 : 135, 1890.
  - *(Bouteloua racemosa.)* B. 12 :121, 1890.

Grand—
  - Island, Nebraska. Beet sugar factory. B. 42 :42, 1898.
  - Junction, Colorado—
    - Fruit growers association report. B. 122 :10, 1907.
    - precipitation. 1885-1911, B. 182 :55, 1912; 1885-1917. B. 245 :61, 1918.
  - Valley, Mesa County, Colorado.
    - description. B. 223 :7, 1917.
    - fruit map. B. 223 :21, 1917.
    - fruit shipped from. B. 223 :26, 1917.
    - fruit survey. B. 223 :3. 1917.
    - niter soils reclaimed. B. 235 :3, 1918.
    - soil analysis. B. 42 :24, 1898.
    - sugar beet, notes. B. 42 :14, 1898.

Grape—
  - anthracnose *(Sphaceloma ampelinum.)* B. 69 :14, 1902.
  - flea beetle *(Graptodera chalybaea.)* B. 71 :18, 1902; B. 114:23, 1906.
  - leaf hopper *(Typhlocyba)*—
    - description and remedies. B. 47 :26, 1898; B. 71 :18, 1902; B. 114 :23, 1906.
    - *See also.* Grape-vine leaf-hopper.

Grape growing. O. B. Whipple. B. 141, 1909.

Grapes—
  - black, varieties. B. 29 :17, 1894.
  - cost of growing. B. 141 :16, 1909.
  - culture. B. 29 :15, 1894; B. 141 :3, 1909.
  - diseases. B. 141 :15, 1909.
  - growing, notes. B. 118 :13, 1907; P. B. 43, 1907.
  - insects injurious to. B. 71 :17, 1902; B. 114 :22, 1905; B. 141 :14, 1909; B. 210 :35, 1915.
  - irrigation. B. 141 :5, 1909.
  - packing. B. 141 :12, 1909.
  - pruning. B. 141 :7, 1909.
  - red, varieties. B. 29 :20, 1894.
  - varieties. R. 2 :24, 1889; B. 17 :36, 1891; B. 21 :15, 1892; B. 141 :13, 1909; B. 223 :47, 1917.
  - white, varieties. B. 29 :22, 1894.
  - winter protection. B. 141 :11, 1909.

Grapevine—
  - leaf hopper *(Typhlocyba vitifex.)* B. 15:18, 1891; B. 19 :16, 1892. *See also* Grape leaf-hopper.

Graphephorum wolfii. B. 12 :95, 1890.

Graptodera—
  - *chalybaea.* See Grape flea-beetle.
  - *foliacea.* See Apple-leaf beetle.

Grass and forage plants experiments with the U. S. in co-operation. A. H. Danielson. R. 14 :33, 1901.

Grass station, Report of,
  - 1890. C. S. Crandall. R. 3 :156.
  - 1891. C. S. Crandall. R. 4 :21.

Grass steppe in Colorado. B. 224 :33, 1917.

Grasses—
  - analysis. B. 12 :5, 1890.
  - brome grass study. B. 190, 1913.
  - description. B. 12 :6, 1890.
  - notes. B. 2 :7, 1887.

Grasshoppers—
  - balloon catcher, description. B. 233 :11, 1917.
  - control—
    - artificial. B. 233 :9, 1917.
    - natural. B. 233 :7, 1917.

- Grasshoppers (Continued)—
  - Control (Continued)—
    - work 1916. B. 233 :20, 1917.
  - diseases. B. 233 :17, 1917.
    - Australian fungus. B. 94 :5, 1904.
  - food habits. B. 233 :6, 1917.
  - hopperdozer, description. B. 112 :3, 1906; B. 233 :10, 1917.
    - experiments. B. 112 :6, 1906.
  - insecticides for. B. 233 :14, 1917.
  - life habits. P. B. 19, 1903; P. B. 38, 1907; B. 123 :17, 1907; B. 233 :3, 1917.
  - live hopper machine. B. 233 :12, 1917.
  - notes. R. 6 :51, 1893; B. 114 :11, 1906; B. 210 :16, 1915.
  - remedies. B. 47 :47, 1898; B. 71 :9, 1902; R. 15 :104, 1902; P. B. 19, 1903; B. 94 :5, 1904; P. B. 38, 1907; B. 123 :17, 1907.
- Grasshopper control. Charles R. Jones. B. 233, 1917.
- Grasshoppers, their habits and remedies. C. P. Gillette. P. B. 19, 1903.
- Grasshoppers upon the plains. C. P. Gillette. P. B. 38, 1907; Same. B. 123 :17, 1907.
- GRAY, DAVID
  - Horse Breeding Experiment Station, Report of. R. 30-31, 1917-1918.
- Greasewood *(Sarcobatus vermiculatus)*—
  - distribution in Colorado. B. 224 :44, 1917.
  - notes. B. 211 :27, 1915.
- Green aphis and the wooly aphis of the apple. C. P. Gillette. P. B. 31, 1907.
- Green aphis of apple. See Apple aphis, green.
- Green arsenoid. See Scheele's green.
- Green cabbage worm. See Cabbage butterfly, imported.
- Green peach aphis. See Peach aphis, green.
- GRIFFIN, H. H.
  - Arkansas Valley Experiment Station report. R. 11-15, 1898-1902,
  - Cantaloupe blight. P. B. 4, 1900; Same. B. 64 :12, 1901.
  - Cantaloupes. B. 62, 1901.
  - Feeding beet pulp to lambs. B. 76, 1902.
  - Pasture grasses. Leguminous crops. Cantaloupe blight. Arkansas substation. B. 68, 1902.
  - San Luis Valley Experiment Station report. R. 1-3, 1888-1890.
- GRIFFIN, H. H. (Continued)—
  - Tomato industry of the Arkansas Valley. R. 78, 1903.
  - See Watrous, Frank L. jt. author. B. 61, 1900.
- GRIFFITH, CLARENCE J.
  - See Buffum, Burt C. jt. author. B. 73, 1902; B. 74, 1902; B. 75, 1902.
  - See Carlyle, William L. jt. author. B. 97, 1905; B. 102, 1905.
- *Grindelia squarrosa.* B. 23 :9, 1893.
- Ground water. See Water, ground.
- Gummosis, notes. B. 118 :9. 1907; P. B. 43, 1907.
- Gunnison Valley, soil analysis. B. 42 : 34, 1898.
- *Gymnosporangium.* See Quince rust.
- Hair grass *(Deschampsia caespitosa.)* B. 12 :72, 1890.
- HALLIDAY, EVELYN G.
  - Home economics section, Report of. R. 31, 1918.
- *Haltica ignita.* See Apple flea-beetle.
- Hamps, Elbert County, Colorado—
  - precipitation. 1893-1911, B. 182 :53, 1912; 1893-1917, B. 245 :58, 1918.
- Harrowing on dry land. B. 103 :5, 1905.
- Harvesting and storing vegetables for home use. J. J. Gardner. B. 232, 1917.
- Hatch act, extracts. R. 10 :10, 1897.
- Hay—
  - native—
    - analysis, tables. B. 124 :31, 1907.
    - calorific value. B. 124 :35, 1907.
    - coefficient of digestion. B. 124 : 34, 1907.
    - compared with alfalfa. B. 124 : 36, 1907.
    - digestibility. B. 93 :9, 1904; B. 93 :31, 1904.
    - furfurol in. B. 124 :34, 1907.
    - methoxyl in. B. 124 :35, 1907.
    - water measurment applied to. B. 22 :16, 1893.
  - shipped into Colorado. B. 153:13, 1910.
- HAYNES, H. N.
  - Distribution of water. Power and duties of irrigation officials in Colorado. B. 67, 1901.
- HEADDEN, WILLIAM PARKER.
  - Alfalfa. B. 35, 1896.
  - Alfalfa. (Results obtained at the Colorado Experiment Station.- B. 110, 1906.
  - Alfalfa. (A synopsis of bulletin

Headden, William Parker (continued)
  35.) B. 111, 1906.
  Alkalis in Colorado (including nitrates.) B. 239, 1918.
  Arsenical poisoning of fruit trees. B. 131, 1908.
  Arsenical poisoning of fruit trees. B. 157, 1910.
  Australian saltbush, its composition and digestibility. Notes on Russian thistle. B. 135, 1908.
  Best time to cut alfalfa. P. B. 13, 1902.
  Black alkali in the San Luis Valley. B. 231, 1917.
  Chemistry section, Report of. R. 6-31, 1893-1918.
  Colorado fodders; an examination into their composition and comparative value. B. 124, 1907.
  Colorado fodders. A study of comparative values based on bulletin 124. B. 125, 1907.
  Colorado hays and fodders. Alfalfa, timothy, native hay, corn, sorghum, salt bush. Digestion experiments. B. 93, 1904.
  Colorado irrigation waters and their changes. B. 82, 1903.
  Conclusions relative to the culture of sugar beets. P. B. 10, 1901.
  Destruction of concrete by alkali. B. 132, 1908.
  Deterioration in the quality of sugar beets due to nitrates formed in the soil. B. 183, 1912.
  Fixation of nitrogen in some Colorado soils. B. 155, 1910.
  Fixation of nitrogen in some Colorado soils. A further study. B. 178, 1911.
  Fixation of nitrogen in Colorado soils. The distribution of the nitrates and their relation to the alkalis. B. 186, 1913.
  How can we maintain the fertility of our Colorado soils? B. 99, 1905.
  Irrigation waters and their effects. B. 83, 1903.
  Nitrates in the soil, an explanation of the so-called "Black alkali" or "Brown spots." B. 160, 1910.
  Properties of Colorado wheat. B. 237, 1918.
  A soil study. Part 1. The crop grown, sugar beets. B. 46, 1898.
  A soil study. Part 2. The crop grown, sugar beets. B. 58, 1900.
  A soil study. Part 3. The soil. B. 65, 1901.
  A soil study. Part 4. The ground water. B. 72, 1902.

Headden, William Parker (continued)
  A study of alfalfa and some other hays. B. 39, 1897.
  A study of Colorado wheat. Part 1. B. 208, 1915.
  A study of Colorado wheat. Part 2. B. 217, 1916.
  A study of Colorado wheat. Part 3. B. 219, 1916.
  A study of Colorado wheat. Part 4. B. 244, 1918.
  A study of Colorado wheat; a resume of bulletins 205, 208, 217, 219, 237, and 244. B. 247, 1918.
  Sugar beets, a resume of the work done by the Agricultural Experiment Station of Colorado. B. 63, 1901.
  Waters of the Rio Grande. a contribution to the hydrology of the San Luis Valley, Colorado. B. 230, 1917.
  Yellow berry in wheat. Its cause and prevention. B. 205, 1915.
  —and Douglass, Earl.
  Deterioration of manures under semi-arid conditions. B. 168, 1910.
  See Cooke, W. W. jt. author. B. 42, 1898.

Heliothis armigera. See Corn ear-worm.
Hellebore, white *(Vertrum speciosum)*—
  notes. B. 71 :25, 1902; B. 114 :34, 1906; B. 210 :45, 1915.
  value as an insecticide. B. 6 :5, 1888.
Hemiptera, list. B. 31, 1895.
Hemp, notes. B. 2 :5, 1887.
Henbane, black *(Hyoscyamus niger)*—
  poisoning. B. 211 :63, 1915.

Herrick, Robert S.
  Horticulturist, Field, Report of. R. 22-24, 1909-1911.
  Thinning the winesap. Winter and frost injuries of fruit tree. B. 170, 1910.
  —and Bennett, E. R.
  Colorado raspberry industry. B. 171, 1910.

Heterocera, list of Colorado. B. 43:5, 1898.
Hierochloa borealis. See Holy grass.
Hilaria jamesii. B. 12 :114, 1890.
Hoehne, Las Animas County—
  precipitation. 1897-1917, B. 245 :63, 1918.
Hog cholera—
  cause. B. 197 :3, 1914.
  control. B. 197 :9, 1914.
  description. B. 197 :4, 1914.
  notes. B. 137 :11, 1909.

- Hog Cholera (Continued)—
  - spread. B. 197 :8, 1914.
  - susceptibility to pigs. B. 197 :4, 1914.
- Hog cholera control. G. H. Glover. B. 197, 1914.
- Hogs. See Pigs.
- Hold-over blight in the pear. Walter G. Sackett. B. 177, 1911.
- Holy grass *(Hierochloa borealis.)* B. 12:106, 1890.
- Home economics section, Report of.
  - 1917. I. M. K. Allison. R. 30 :27.
  - 1918. E. G. Halliday. R. 31 :28.
- Home garden; hints to settlers. J. E. Payne. P. B. 50. 1910.
- Home grown grain vs. corn for fattening hogs. Other trials with corn, barley, alfalfa, and beets. Swine feeding in Colorado. Beet pulp and sugar beets for fattening hogs. B. C. Buffum and H. H. Griffin. B. 74, 1902.
- Home made cider vinegar. Walter G. Sackett. B. 192, 1913.
- Home vegetable garden. R. A. McGinty. B. 241, 1918.
- Honey—
  - comb foundation—
    - methods of using. B. 54 :18, 1900.
    - notes. B. 54 :3, 1900.
    - weight of artificial. B. 54 :5, 1900.
    - weight of artificial compared to natural. B. 54 :11, 1900.
  - pollen substitutes. B. 54 :23, 1900.
  - wax proportion in. B. 54 :20, 1900.
- Hook-gage. B. 49 :13, 1898.
- Hop plant louse *(Phorodon humuli.)* B. 133 :40. 1908; B. 134:14, 1908.
- Hopperdozer—
  - description. B. 112, 1906; B. 233 :10, 1917.
- Hopperdozer. P. K. Blinn. B. 112, 1906.
- *Hordeum jubatum.* See Squirrel tail grass.
- Horse Breeding Station, Carriage—
  - information concerning. B. 166. 1910.
  - notes. R. 20 :37, 1907.
  - pedigree of stock at. B. 166 :9, 1900; R. 22 :52, 1909.
- Horse Breeding Station, Report of.
  - 1909. J. O. Williams. R. 22 :50.
  - 1910. J. O. Williams. R. 23 :89.
  - 1911. J. O. Williams. R. 24 :68.
- Horse Breeding Station, Report of (Continued)—
  - 1912. J. O. Williams. R. 25 :44.
  - 1913. J. O. Williams. R. 26:24.
  - 1914. W. P. Little. R. 27 :25.
  - 1915. W. P. Little. R. 28 :29.
  - 1916. W. P. Little. R. 29 :28.
  - 1917. D. D. Gray. R. 30 :28.
  - 1918. D. D. Gray. R. 31 :33.
- Horsetail poisoning in animals. B. 211 : 15, 1915.
- Horticultural section, Report of,
  - 1910. E. R. Bennett. R. 23 :101.
  - 1911. E. R. Bennett. R. 24 :53.
  - 1912. E. R. Bennett. R. 25:39.
  - 1913. E. P. Sandsten. R. 26 :29.
  - 1914. E. P. Sandsten. R. 27 :31.
  - 1915. E. P. Sandsten. R. 28 :23.
  - 1916. E. P. Sandsten. R. 29 :30.
  - 1917. E. P. Sandsten. R. 30 :26.
  - 1918. E. P. Sandsten, R. 31 :29.
  - For earlier reports *see* Botanical and Horticultural section, Report.
- Horticulture, Botany, and Entomology department—
  - work. B. 5 :4, 1887.
- Horticulture and potato investigations report. E. R. Bennett. R. 22 :36, 1909.
  - For later reports *see* Horticultural section, Report of.
- Horticulturist, field, Report of,
  - 1906 O. B. Whipple. R. 19 :135.
  - 1907. O. B. Whipple. R. 20 :31.
  - 1908. O. B. Whipple. R. 21:143.
  - 1909. R. S. Herrick. R. 22 :38.
  - 1910. R. S. Herrick. R. 23 :85.
  - 1911. R. S. Herrick. R. 24 :59.
- Hotbeds—
  - construction. B. 199 :35, 1914; B. 221 :3, 1917.
- Hotbeds and cold frames. R. A. McGinty. B. 199 :35. 1914.
- Hotbeds and cold frames. T. F. Limbocker. B. 221. 1917.
- HOUSE, EDWARD B.
  - Cost of Colorado roads. P. B. 29, 1907.
  - Irrigation by means of underground porous pipe. B. 240, 1918.
  - Meteorological and irrigation engineer report. R. 24-30, 1911-1917.
- How can we maintain the fertility of our Colorado soils? W. P. Headden. B. 99, 1905.
- How to fight the codling moth. C. P. Gillette. P. B. 11. 1901; B. 64 :26, 1901.
- Howard scale *(Aspidiotus Howardi)*—
  - bibliography. B. 120 :18, 1907.
  - description. B. 114:16, 1906; B.

Howard scale (continued)—
- 120 :6, 1907.
- enemies of. B. 120 :10, 1907.
- food plants. B. 120 :4, 1907.
- history. B. 120 :3, 1907; P. B. 30, 1907.
- injuries by. B. 120 :5, 1907.
- means of distribution. B. 120 :8. 1907.
- notes. B. 38 :37. 1897; R. 15 :107, 1902; B. 114 :6, 1906; B. 114 :14, 1906; B. 119:8, 1907; B. 210 :11, 1915; B. 210 :22, 1915.
- plate describing. R. 14 :16. 1901.
- remedies. B. 71 :14, 1902; B. 120 : 12, 1907; P. B. 30, 1907.

Howard scale. Estes P. Taylor. B. 120, 1907.

Howard scale. Estes P. Taylor. P. B. 30, 1907.

HUFFINGTON, M. J.
- Notes on tomatoes. B. 30 :26, 1894.
- strawberries and grapes. B. 29, 1894.
- See Crandall, Charles S. jt. author. B. 26 :11, 1894.

Humidity in relation to agriculture. B. 224 :26, 1917.

HUNTLEY, FRED A.
- Arkansas Valley Experiment Station report. R. 5-7, 1892-1894.
- Seeding, tillage, and irrigation. B. 26 :25, 1894.

Hyalopterus arundinis. See Mealy plum louse.

Hydraulic equivalents, table. B. 207 :16, 1915.

Hydrocyanic acid gas—
- as an insecticide. B. 71 :32, 1902; B. 114 :40, 1906; B. 210:50, 1915.

Hymenoxys floribunda. See Rubber plant. Colorado.

Hyoscyamus niger. See Henbane, black.

Hyphantria cunea. See Fall web-worm.

Hypholoma. B. 201 :26, 1914.

Imported cabbage butterfly. See Cabbage butterfly, imported.

Inch, water. See Water inch.

Index bulletin. W. J. Quick. B. 18, 1891.

Influence of food upon pure fat present in milk. The best milk tester for the practical use of the farmer and dairyman. W. J. Quick. B. 20, 1892.

Information concerning the Colorado Carriage Horse Breeding Station. J. O. Williams. B. 166, 1910.

INGERSOLL, CHARLES L.
- Experiment Station report. R. 1-3, 1888-1890.
- —and O'BRINE, DAVID.
- Sugar beets. B. 11, 1890.

Injurious insects. C. P. Gillette. B. 19, 1892.

Insect—
- traps, description. B. 71 :33, 1902; B. 114 :42, 1906; B. 210 :52, 1915.

Insect enemies of the orchard. C. P. Gillette. B. 38, 1897.

Insect pests. A few common. C. P. Gillette. B. 38, 1897.

Insect pests and their remedies. Colorado's. C. P. Gillette. B. 47, 1898.

Insecticides—
- application. B. 71:35, 1902, B. 114 :43, 1906; B. 210 :53, 1915.
- arsenical. B. 6 :4, 1888.
- experiments. B. 11 :163, 1898.
- for grasshoppers. B. 233:14, 1917.
- notes. P. B. 20, 1903.
- preparation and use. B. 6 :4, 1888; B. 47 :54, 1898; B. 71 :20, 1902; P. B. 21, 1904; B. 114 :28, 1906; B. 210 :42, 1915.

Insects and insecticides. J. Cassidy. B. 6, 1888.

Insects and insecticides. C. P. Gillette. B. 71, 1902.

Insects and insecticides. C. P. Gillette. B. 114, 1906.

Insecticides. (Revision of B. 114.) C. P. Gillette and G. M. List. B. 210, 1915.

Instructions for co-operative tree planting. B. O. Longyear. P. B. 25, 1906.

Investigations of the Great Plains. Unirrigated lands of eastern Colorado. Seven years study. J. E. Payne. B. 77, 1903.

Irish potatoes. Fruit raising. Sugar beets. F. L. Watrous. B. 21, 1892.

Irrigated agriculture in the San Luis Valley. V. M. Cone and Alvin Kezer. B. 209, 1915.

Irrigation—
- administration of Colorado. B. 67 : 3, 1901.
- changes in water due to. B. 82 :28, 1903.
- early. B. 59 :9, 1900.
- effect at head of stream. B. 33 :57, 1896.
- experiments in. B. 1:4, 1887.
- law (Colorado.) B. 67 :5, 1901.
- land under, 1889. R. 2 :56, 1889;

- Irrigation (Continued)—
    - R. 3 :73, 1890.
    - literature, list of. R. 3 :79, 1890.
    - removal of nitrates by. B. 72 :42, 1902.
    - superintendent's powers and duties. B. 67 :19, 1901.
    - underground. See Sub-irrigation.
    - water—
        - changes in. B. 82, 1903.
        - commissioner's powers and duties. B. 67 :8, 1901.
        - division. B. 13, 1890 ; B. 27, 1894.
        - measurement. B. 13, 1890.
            - Dethridge meter. B. 215 :3, 1915.
            - divisors. B. 228 :3, 1917.
        - supply in state. R. 3 :58, 1890.
    - wind mill for plains. P. B. 53, 1910.
    - *See also* water.
- Irrigation and drainage section, Report of,
    - 1911. V. M. Cone. R. 24:24.
    - 1912. V. M. Cone. R. 25 :28.
    - 1913. V. M. Cone. R. 26 :27.
    - 1914. V. M. Cone. R. 27 :28.
    - For later reports *see* Irrigation investigations.
- Irrigation and meteorology department—
    - work. Spec. B. "A" :8, 1892.
- Irrigation and meteorology, Experiments in. Elwood Mead. B. 1, 1887.
- Irrigation by means of underground porous pipe. E. B. House. B. 240, 1918.
- Irrigation engineers report. See Meteorological and engineering report.
- Irrigation investigations section, Report of.
    - 1915. V. M. Cone. R. 28 :16.
    - 1916. V. M. Cone. R. 29 :35.
    - 1917. V. M. Cone. R. 30 :28.
    - 1918. R. Parshall. R. 31 :37.
- Irrigation waters and their effects. W. P. Headden. B. 83, 1903.
- Iva—
    - *axillaris.* See Poverty weed.
    - *xanthifolia.* B. 23:9, 1893.
- *Jassidae,* list in college collection. B. 43 :31, 1898.
- Jimson weed, poisoning. B. 211 :64, 1915.
- JOHNSON, SAMUEL ARTHUR.
    - Cottony maple scale. B. 116. 1906 ; P. B. 27, 1906.
    - cutworms. B. 98, 1905.
    - plant lice and their remedies. P.

- JOHNSON, SAMUEL ARTHUR (Continued)
    - B. 20, 1903.
    - Potato flea beetle. P. B. 23, 1904.
    - Potato insects. B. 175 :42, 1910.
    - Western cricket. Migratory habits. B. 101 :11, 1905.
- Johnson grass, poisoning. B. 211 :17, 1915.
- JONES, CHARLES R.
    - Grasshopper control. B. 233. 1917.
- JONES, P. S. See Cone, V. M. jt. author. B. 194, 1914.
- *Juncus*—
    - *balticus.* See Wire grass.
    - *bufonius.* B. 12 :126, 1890.
    - *mertensianus.* See Bog rush.
- Junipers—
    - description. B. 130:29, 1908.
    - distribution in Colorado. B. 224 : 46, 1917.
    - varieties. B. 130 :30, 1908.
- Kaffir corn. B. 2 :6, 1887.
- *Kalmia polifolia.* See Swamp laurel.
- KAUPP. B. F.
    - Some poultry diseases. B. 185, 1912.
    - See Glover, G. H. jt. author. B. 137, 1909 ; B. 162, 1910.
- Kentucky blue grass *(Poa pratensis.)* B. 12 :18, 1890 ; B. 68 :5, 1902.
- Kerosene—
    - as an insecticide. B. 71 :27, 1902 ; B. 114 :35, 1906.
    - emulsion—
        - preparation and use. B. 6 :6, 1888 ; B. 114 :35, 1906 ; B. 133 :44, 1908. B. 134 :14, 1908.
    - milk emulsion, preparation and use. B. 114 :36, 1906.
- KEYSER, ALVIN. See Kezer, Alvin.
- KEZER, ALVIN.
    - Agronomy section, Report of. R. 22-31, 1909-1918.
    - Dry farming in Colorado. B. 227, 1916.
    - Farm costs on the Colorado Agritural College farm. B. 203, 1914.
    - Farm managers report. R. 23 :110, 1910.
    - Flax growing. P. B. 55, 1912.
    - Flax growing. P. B. 58, 1915.
    - Flax seeding. P. B. 57, 1913.
    - Forage crops for the Colorado plains. B. 214, 1915.
    - Treatment of seed grain to prevent smut. P. B. 49, 1909.
    - Variation studies in brome grass, a preliminary report. B. 190, **1913.**
    - —and BOYACK, BREEZE.
    - **Mendelian** inheritance in wheat and

Kezer, Alvin (continued)
barley crosses. B. 249, 1918.
—and Sackett, Walter G.
Beans in Colorado and their diseases. B. 226, 1917.
Beans in Colorado and their diseases. B. 234, 1918.
See Cone, V. M. jt. author. B. 209, 1915.

Kinnison, Florence I.
Forcing strawberries. B. 222, 1917.

Knorr, Fritz.
Agronomy section, Report of, R. 21 :31, 1980.
Agronomy section, Crop nursery division. R. 19 :159, 1906.

Koeleria cristata. B. 12 :110, 1890.

Kohl-Rabi. B. 199 :16, 1914 ; B. 241 :20, 1918.

Kutter's formula. B. 150 :37, 1909 ; B. 194:38, 1914.

Lamb feeding experiments 1900/2. Sugar beets and sugar beet pulp. Home grown grains and corn. Small grain and corn. Warm and cold water. Shropshire grades and native lambs. B. C. Buffum and C. J. Griffith. B. 75, 1902.

Lambs—
Alfalfa hay for. B. 151 :3. 1910.
alfalfa meal for. B. 187 :12. 1913.
barley for. B. 187 :12, 1913.
feeding experiments, 1900/2, B. 75, 1902 ; 1906/7, 1907/8, B. 151, 1910 ; 1908/9, 1909/10, 1910/11, B. 187, 1913.
loss caused by dogs. B. 187 :4, 1913.
raising. B. 52 :24, 1899.
Shropshire vs. native. B. 75 :28, 1902.
sugar beets for. B. 75 :7, 1902.
sugar beet pulp for. B. 75 :7, 1902 ; B. 76, 1902.
See also Sheep.

Lantern trap for insects. B. 43 :22, 1898.

Large potato vines and no potatoes. Wendell Paddock. B. 92, 1904.

Larimer and Weld Canal—
water for irrigation. B. 22 :27, 1893.

Larimer and Weld Reservoir—
water analysis. B. 82:19, 1903.

Larkspur *(Delphinium)*—
ash analysis. B. 25 :25, 1893.
description. B. 25 :22, 1893 ; B. 113:13, 1906.

Larkspur *(Delphinium)* (Continued) —
notes. B. 137 :6, 1909 ; B. 211 :29, 1915.
poisoning. B. 211 :31, 1915.
experiments. B. 113 :16, 1906.
symptoms. B. 113 :14, 1906.
treatment. B. 113 :14, 1906.

Larkspur and other poisonous plants. G. H. Glover. B. 113, 1906.

Laying down of peach trees. Wendell Paddock. B. 80, 1903.

Le Roy, Logan County, Colorado—
precipitation. 1889-1911, B. 182 :53, 1912 ; 1889-1917, B. 245:58, 1918.

Lead arsenate. B. 71 :23, 1902 ; B. 114 : 31, 1906 ; B. 210 :44, 1915.

Leaf—
crumpler *(Phycis indiginella.)* R. 13 :124, 1900.
hopper *(Typhlocyba.)* R. 13 :126, 1900.
roller. R. 6 :52, 1893 ; R. 13 :123, 1900.

Leersia orysoides. B. 12 :105, 1890.

Left Hand Creek—
seepage—
gains and losses. 1899-1903, B. 180, pt. 1 :38, 1911 ; B. 180, pt. 3 :139, 1911.
measurement. R. 13:137, 1900.
water measurement. 1899-1903. B. 180, pt. 3 :32, 1911.

Leguminous crops. Cantaloupe blight (Arkansas Valley.) Pasture grasses, H. H. Griffin. B. 68, 1902.

Lehi, Utah. Beet sugar factory. B. 42 :45, 1898.

Lema trilineata. B. 6 :19, 1888.

Lepidoptera, list. B. 43 :3, 1898.

Lepidosaphes ulmi. See Oyster-shell bark-louse.

Lepiota. B. 201 :19, 1914.

Leptinotara decemlineata. See Potato beetle, Colorado.

Leptocoris trivittatus. See Box elder plant bug.

Lettuce—
fungous diseases of. B. 212 :31, 1915.
notes. B. 199 :16, 1914 ; B. 241 :21, 1918.

Lichens, non-poisonous to stock. B. 211 :12, 1915.

Life and care of farm machinery in Colorado. H. M. Bainer and H. B. Bonebright. B. 167, 1910.

Limbocker, T. Forest.
Hotbeds and cold frames. B. 221,

Limbocker, T. Forest (Continued)—1917.
  See Sandsten, E. P. jt. author. B. 223, 1917.

Lime—
  arsenite, notes. B. 71:24, 1902; B. 114, 32, 1906.
  as an insecticide. B. 71:29, 1902; B. 114:37, 1906; B. 210:47, 1915.

Lime and sulphur mixture—
  for Howard's scale. B. 120:15, 1907.
  preparation and use. B. 133:47, 1908; B. 134:16, 1908; B. 212:52, 1915.

LIST, GEORGE M. See Gillette, C. P. jt. author. B. 210, 1915.

List of original types of species in the super family *Jassoidea* in collection. B. 43:30, 1898.

LITTLE, WILLIAM P.
  Horse Breeding Experiment Station, Report of. R. 27-29, 1914-1916.

Little Thompson River—
  seepage—
    gains and losses. 1897-1910, B. 180, pt. 1:36, 1911; B. 180, pt. 3:137, 1911.
    measurement. R. 12:45, 1899; R. 13:136, 1900; 1900-1910, B. 180, pt. 3, Measurement 1-11, 1911.

Live stock poisoning. B. 113, 1906.

Loco and larkspur. David O'Brine. B. 25, 1893.

Loco weed—
  analysis methods. B. 25:18, 1893.
  ash analysis. B. 25:25, 1893.
  description. B. 25:3, 1893.
  notes. B. 137:5, 1909.
  poisoning. B. 211:46, 1915.
    effect on nervous system. B. 25:12, 1893.
    of cattle. B. 87:16, 1904.
    post mortem examination. B. 25:7, 1893.
  varieties. B. 211:43, 1915.

Locust—
  borer (*Cyllene robiniae* Forst)—
    notes. P. B. 32, 1907; B. 210:38, 1915.
    remedies. P. B. 32, 1907.
  tree pruning. P. B. 41, 1907.

Locust borer (*Cyllene robiniae* Forst.) C. P. Gillette. P. B. 32, 1907.

Locusts. See Grasshoppers.

Lodge pole pine. See Pines, lodge pole.

Loganberries, notes. B. 136:8, 1909.

Loganberry, culture. B. 195:10, 1914.

Lolium perenne. See Rye grass.

Lolium perenne var. *Italicum.* See Rye grass, Italian.

London purple, notes. B. 71:24, 1902; B. 114:33, 1906.

Long Pond (Fort Collins) water analysis. B. 82:22, 1903.

LONGYEAR, BURTON O.
  Botanical section, Report of. R. 22-27, 1909-1914.
  Dandelion in Colorado. B. 236, 1918.
  The evergreen trees of Colorado. B. 130, 1908.
  Forestry section, Report of. R. 19-20, 1906-1907, R. 28-31, 1916-1918.
  Instructions for co-operative tree planters. P. B. 25, 1906.
  A new apple rot. B. 105, 1905.
  Pruning locust and catalpa trees for timber. P. B. 41, 1907.
  Some Colorado mushrooms. B. 201, 1914.
  Strawberry growing in Colorado. B. 140, 1909.
  Wind-breaks and shelter belts for the plains. P. B. 35, 1907; B. 123:15, 1907.
  See Paddock, Wendell. jt. author. P. B. 22, 1905; B. 96, 1905.

Loss of water from reservoirs by seepage and evaporation. L. G. Carpenter. B. 45, 1898.

Losses from canals from filtration or seepage. L. G. Carpenter. B. 48, 1898.

Loxostege sticticalis. See Beet webworm.

Lupines *(Lupinus.)* poisoning. B. 113:21, 1906; B. 211:42, 1915.

Lupinus—
  argentens. B. 12:128, 1890.
  argentens var. *argophyllus.* B. 12:128, 1890.
  See also. Lupines.

Luzula spadicea var. *subcongesta.* B. 12:127, 1890.

Lye, as an insecticide. B. 114:37, 1906.

Lyme grass. See *Elymus.*

Lyons Brothers Company.
  Early market conditions of cantaloupes on the New York market. B. 108:13, 1906.

MCCANN, ROUD.
Testing and handling of milk and cream. B. 202, 1914.

- McCLELLAND, J. H.
  - Divide Experiment Station report. R. 6-8, 1893-1895.
- McDOWELL, R. H.
  - Agricultural section, Report of. R. 3, 1890.
- McEACHRAN, WILLIAM.
  - Veterinary section, Report of. R. 1-2, 1888-1889.
- McGINTY, R. A.
  - Home vegetable garden. B. 241, 1918.
  - Vegetable gardening in Colorado. Hot beds and cold frames. B. 199, 1914.
  - See Sandsten, E. P. jt. author. B. 223, 1917.
- Machine house plan. B. 167 :15, 1910.
- Magnesium compounds in soils. B. 196 :38, 1914.
- *Malacosoma fragilis.* See tent caterpillar.
- Manure—
  - carbon in. B. 168 :22, 1910.
  - cattle, analysis. B. 168 :23, 1910.
  - deterioration. B. 168, 1910.
  - free ammonia in. B. 168 :18, 1910.
  - fresh, use. B. 168:3, 1910.
  - green. B. 99 :11, 1905.
  - hydrogen in. B. 168 :22, 1910.
  - liquid wastes of. B. 168 :4, 1910.
  - sheep, analysis. B. 168 :12, 1910.
- Maple scale, cottony *(Pulvinaria innumerabilis)*—
  - bibliography. B. 116 :16, 1906.
  - description and remedies. B. 47 :33, 1898; B. 114 :22, 1906; P. B. 27, 1906.
  - distribution. B. 116 :4, 1906
  - enemies. B. 116 :10, 1906.
  - food plants. B. 116 :5, 1906.
  - history. B. 116:6, 1906.
  - notes. R. 10 :59, 1897; B. 210 :36, 1915.
  - remedies. B. 71 :17, 1902; B. 116 : 11, 1906.
  - spread of. B. 116 :9, 1906.
- Market development of Rocky Ford cantaloupe. W. Woods. B. 108 :14, 1906.
- MEAD, ELWOOD.
  - Report of experiments in irrigation and meteorology. B. 1, 1887.
- Meadow—
  - fescue. See Fescue grass.
  - hay. B. 39 :30, 1897.
- Mealy plum louse *(Hyalopterus arundinis)*—
  - description. B. 133 :39, 1908; B. 134 :13, 1908.
- Measurement and division of water. L. G. Carpenter. B. 13, 1890.
- Measurement and division of water. L. G. Carpenter. B. 27, 1894.
- Measuring worm. B. 62 :17 1901.
- Mediterranean flour moth., See Flour moth, Mediterranean.
- Meeker, Colorado, precipitation. 1891-1911, B. 182 :56, 1912; 1891-1917, B. 245 :62, 1918.
- *Melica spectabile.* B. 12 :95, 1890.
- Melon—
  - aphis *(Aphis gossypii.)* B. 199 :44, 1914.
  - louse *(Aphis cucumeris.)* B. 47 :40, 1898; B. 62 :17, 1901.
- Mendelian law, summary. B. 249 :28, 1918.
- Mendelian inheritance in wheat and barley crosses. Alvin Kezer and Breeze Boyack. B. 249, 1918.
- Mesa County fruit survey. B. 223 :3, 1917.
- Meteorological—
  - observations. 1891, R. 4 :33, 1891; 1898-99, R. 12 :96, 1899; R. 13 : 165, 1900. R. 15:153, 1902.
  - Akron. B. 1:12, 1887.
    - Cheyenne Wells. B. 49 :50, 1898.
    - Eastonville. B. 1 :12, 1887.
    - Fort Collins. B. 1 :12, 1887; R. 1 :168, 1888; R. 2 :58, 1889; R. 3 :90, 1890; B. 49 :20, 1898.
      - temperature. B. 127, 1908; B. 245 :16, 1918.
    - Grand Junction. B. 1 :12, 1887.
    - Laramie River. B. 49:53, 1898.
    - Long's Peak. B. 49 :52, 1898.
    - Pinkhampton. B. 49 :52, 1898.
    - Rocky Ford. B. 49 :49, 1898.
- Meteorological and irrigation engineering—
  - report,
    - 1888. L. G. Carpenter. R. 1 :153.
    - 1889. L. G. Carpenter. R. 2 :49.
    - 1890. L. G. Carpenter R. 3 :57.
    - 1891. L. G. Carpenter. R. 4 :29.
    - 1892. L. G. Carpenter. R. 5 :30.
    - 1893. L. G. Carpenter. R. 6 :44.
    - 1894. L. G. Carpenter. R. 7:52.
    - 1895. L. G. Carpenter. R. 8 :108.
    - 1896. L. G. Carpenter. R. 9 :149.
    - 1897. L. G. Carpenter. R. 10 :62.
    - 1898. L. G. Carpenter. R. 11 : 171.
    - 1899. L. G. Carpenter. R. 12 :42.
    - 1900. L. G. Carpenter R. 13 : 132.

Meteorological and Irrigation Engineering (Continued)—
  - 1901. L. G. Carpenter. R. 14 :39.
  - 1902. L. G. Carpenter. R. 15 : 137.
  - 1903. No report.
  - 1904. L. G. Carpenter. R. 17 : 108.
  - 1905. L. G. Carpenter. R. 18:47.
  - 1906. L. G. Carpenter. R. 19 : 150.
  - 1907. L. G. Carpenter. R. 20 :46.
  - 1908. No report.
  - 1909. L. G. Carpenter. R. 22 :22.
  - 1910. No report.
  - 1911. E. B. House. R. 24 :22.
  - 1912. E. B. House. R. 25 :27.
  - 1913. E. B. House. R. 26 :25.
  - 1914. E. B. House. R. 27 :27.
  - 1915. E. B. House. R. 28 :27.
  - 1916. E. B. House. R. 29 :35.
  - 1917. E. B. House. R. 30:29.
- For later reports *see* Engineering division, Report of.
- work of department. B. 5 :5, 1887.

Meteorology of 1897, with illustrations. L. G. Carpenter and R. E. Trimble. B. 49, 1898.

Methoxyl—
- in alfalfa. B. 124:18, 1907.
- in corn fodder. B. 124 :45, 1907.
- in native hay. B. 124 :33, 1907.
- in salt bush. B. 124 :66, 1907.
- in sorghum fodder. B. 124 :59, 1907.
- in timothy. B. 124 :29, 1907.

MEYER, A. J. See Carlyle, W. L. jt. author. B. 97, 1905.

Micro-organisms effect on the soil. B. 196, 1914.

Mildews, poisoning in animals. B. 211 : 8, 1915.

Milk—
- clean production. B. 156 :4, 1910.
- fat as effected by food. B. 20 :11. 1892.
- skimming for butter. B. 163 :5, 1910.
- testing apparatus and methods. B. 20 :3, 1892 ; B. 202 :5, 1914.

Milkweed *(Asclepias)*—
- beetle *(Tetraopes femoratus)* B. 47 :37, 1898.
- poisoning. B. 211 :58, 1915.
- whorled—
  - distribution (map.) B. 246 :7, 1916.
  - experiments. B. 246 :10, 1918.
  - plants resembling. B. 246 :8, 1918.
  - history. B. 246 :3, 1918.

Millet—
- foxtail *(Setaria italica)*—
  - smuts on. B. 242 :5, 1918.
- notes. B. 2 :9, 1887 ; B. 30 :6, 1894.
- on plains lands. B. 214:19, 1915.
- panicum, smuts on. B. 242 :8, 1918.
- smut—
  - control. B. 238 :29, 1918 ; B. 242 :17, 1918.
  - source of infection. B. 242 :10, 1918.
  - spores vitality. B. 242 :12, 1918.
- varieties. B. 30 :6, 1894.

Millet smuts and their control. H. E. Vasey. B. 242, 1918.

Mineral substances, changes in soil due to. B. 196 :34, 1914.

Miner's inch—
- definition. B. 207 :3, 1915.
- devices for (map.) B. 207 :9, 1915.

Modules—
- Cippoletti. B. 13 :25, 1890 ; B. 150 :27, 1909.
- description. B. 13 :9, 1890 ; B. 27 : 13, 1894 ; B. 150 :18, 1909.

Moisture, summer culture to conserve. B. 123 :10, 1907 ; P. B. 39, 1907.

Molds, animals poisoned by. B. 211 :10, 1915.

Monkshood. See Aconite.

Monoxia puncticollis. See Sugar beet leaf beetle.

Morchella esculenta. See Morel, common.

Morel, common *(Morchella esculenta.)* B. 201 :11, 1914.

MORTON, GEORGE E.
- Animal husbandry section, Report of R. 22-31, 1909-1918.
- Cost of beef production under semi-arid conditions. B. 189, 1913.
- Feeding experiments with lambs, 1908/9, 1909/10, 1910/11. Alfalfa meal for feeding lambs. Ration experiments with lambs. Loss caused by dogs among lambs. B. 187, 1913.
- Ration experiment with swine, 1908/11. B. 188. 1913.
- See Carlyle, W. L. jt. author. B. 149, 1909 ; B. 151, 1910 ; B. 165, 1910.

Moths, clothes. B. 47 :53, 1898.

Muhlenbergia—
- *glomerata.* B. 12 :137, 1890 ; B. 12 :81, 1890.
- *gracillima.* B. 12:84, 1890.
- *gracilis.* B. 12 :83, 1890.

- Muhlenbergia (Continued)—
  - *gracilis* var. *breviaris*. B. 12 :83, 1890.
  - *wrightii*. B. 12 :82, 1890.
- *Munroa squarrosa*. B. 12 :126, 1890.
- Mushrooms—
  - description. B. 201 :4, 1914.
  - edibility test. B. 201 :4, 1914.
  - gill-bearing. B. 201 :15, 1914.
  - meadow *(Agaricus campester.)* B. 201 :24, 1914.
  - oyster *(Pleurotus sapidus.)* B. 201 : 22, 1914.
  - spring. B. 201:9, 1914.
  - structure. B. 201 :8, 1914.
- Muskmelon. B. 199 :18, 1914 ; B. 241 : 21, 1918.
- *Myochrous squamosus*—
  - pears injured by. B. 119 :15, 1907.
- *Mytilaspis pomorum* See Oyster-shell scale.
- *Myzus*—
  - *cerasi*. See Cherry aphis.
  - *persicae*. See Peach aphis, green.
- Naptheline as an insecticide. B. 114 :41, 1906 ; B. 210 :51, 1915.
- Native vegetation and climate of Colorado in their relation to agriculture. W. W. Robbins. B. 224, 1917.
- *Necrotic*—
  - *dermatitis*—
    - in sheep. B. 137 :4, 1909.
    - *See also*. Sheep, lip and leg ulceration.
  - *stomatitis*—
    - cause. B. 197 :11, 1914.
    - in calves. B. 137 :3, 1909.
    - in pigs. B. 137:3, 1909.
- *Necrotic stomatitis*. I. E. Newsom. B. 197 :11, 1914.
- *Nectria cinnabarina*. See Currant cane disease.
- New alfalfa disease. W. Paddock. P. B. 28, 1906.
- New alfalfa disease, stem blight. (An abbreviated edition of B. 158.) Walter G. Sackett. B. 159, 1910.
- New apple rot. B. O. Longyear. B. 105 1905.
- New poisonous weed, the whorled milkweed. G. H. Glover, I. E. Newsom, and W. W. Robbins. B. 246, 1918.
- NEWSOM, ISSAC E.
  - *Necrotic stomatitis*. B. 197, 1914.
  - Veterinary pathologist report. R. 31 :42, 1918.
  - See Glover, G. H. jt. author. B. 204, 1915 ; B. 229, 1917 ; B. 246, 1918.
- Nightshade—
  - black. B. 211 :60, 1915.
  - three flowered. B. 211 :60, 1915.
- Niter soils, reclaiming. B. 235 :3, 1918.
- Nitrate of soda, use for sugar beets. B. 115 :21, 1906.
- Nitrates—
  - effect on sugar beets. B. 183:71, 1912 ; B. 183 :105, 1912 ; B. 183 : 159, 1912.
  - in—
    - ground water. B. 72 :34, 1902.
    - soil. B. 160, 1910 ; B. 183 :29, 1912 ; B. 239 :10, 1918.
      - causes. B. 160 :7, 1910.
      - distribution. B. 217 :17, 1916.
      - effect. B. 239 :19, 1918.
  - origin. B. 239 :19, 1918.
  - removed by irrigation. B. 72:42, 1902.
- Nitrates in the soil, an explanation of so-called "Black alkali" or "Brown spots." W. P. Headden. B. 160, 1910.
- Nitrification in soils. B. 196 :18, 1914.
- Nitrifying efficiency of certain Colorado soils. Walter G. Sackett. B. 193. 1914.
- Nitrogen fixation in soils. B. 155, 1910 ; B. 160, 1910 ; B. 178, 1911.
- Oak carpenter worm *(Prionoxistus robiniae.)* R. 10 :58, 1897.
- Oat grass, tall *(Avena elatior.)* B. 68 :5, 1902.
- Oats—
  - Australian. B. 2 :12, 1887.
  - cost of growing on college farm. B. 203:22, 1914. (tables.)
  - culture in San Luis valley. B. 209 :26, 1916.
  - fungous diseases of. B. 212 :24, 1915.
  - notes. B. 30 :3, 1894.
  - smut control. B. 238 :28, 1918.
  - varieties. R. 1:52, 1888 ; B. 26 :6, 1894 ; B. 30 :4, 1894.
- O'BRINE, DAVID.
  - Chemistry section, Report of. R. 1-5, 1888-1892.
  - Loco and larkspur. B. 25, 1893.
  - Soils and alkali. B. 9, 1889.
  - Sugar beets. B. 14, 1891.
  - See Cassidy, James. jt. author. B. 7, 1888 ; B. 8, 1889 ; B. 10, 1890 ; B. 12, 1890.
  - See Ingersoll, C. L. jt. author. B. 11, 1890.

Observation on injurious insects. C. P. Gillette. B. 19, 1892.

OLIN, WALTER H.
- Acclimated seeds. Hints for new settlers in eastern Colorado. P. B. 24, 1907; Same. B. 123:12, 1907.
- Agronomy section, Report of. R. 18-20, 1905-1917.
- Cultural methods for sugar beets. Progress bulletin. B. 109, 1906.
- Preparation of seed bed, hints for plains. P. B. 36, 1907; Same. B. 123:9, 1907.
- Seeding field peas. P. B. 40, 1907.
- Summer culture to conserve moisture. Hints for plains settlers. P. B. 39, 1907; Same. B. 123:10, 1907.
- The thorough tillage system for the plains of Colorado. B. 103, 1905.
- Types of milling wheat for the plains. P. B. published in B. 123: 20, 1907.
- —and F. KNORR.
- Formalin treatment of seed grain for smut. P. B. 24, 1906.

On the measurement and division of water. L. G. Carpenter. B. 150, 1909.

Ongarth's tree protector, value of. B. 6:6, 1888.

Onion—
- thrips *(Thrips striatus.)* B. 24:13, 1893; B. 199:45, 1914.
  - remedies. B. 47:44, 1898.

Onion growing in the Cache a la Poudre Valley. Wendell Paddock. B. 81, 1903.

Onions in Colorado. E. R. Bennett. B. 198, 1914.

Onions—
- cost of production. B. 198:7, 1914.
- culture. B. 81:1903; B. 198:3, 1914.
- diseases. B. 81:9, 1903.
- fungous diseases of. B. 212:31, 1915.
- harvesting. B. 198:6, 1914.
- irrigation. B. 198:5, 1914.
- notes. B. 172:10, 1910; B. 199:19, 1914; B. 241:22, 1918.
- seed production. B. 198:8, 1914.
- storage. B. 198:8, 1914.
- varieties. B. 81:7, 1903.

Orange rust *(Caeoma nitens)*—
- notes. B. 41:19, 1898; B. 171:16, 1910; B. 195:18, 1914.

Orchard—
- grass *(Dactylis glomerata.)* B. 68: 4, 1902.
- heating. B. 223:19, 1917.

Orchard plant lice and their remedies. C. P. Gillette and E. P. Taylor. B. 134, 1908.

Orchards—
- cover crops. B. 223:10, 1917.
- fertilizers for. B. 142, 1909.
- food taken from soil by. B. 142:8, 1909.
- notes. R. 1:70, 1888.
- shade crops for. B. 142, 1909.
- spraying costs. B. 223:13, 1917.
- tillage in. B. 142:3, 1909.

Orinthology—
- bibliography. B. 37:20, 1897; B. 44:151, 1898; B. 56:186, 1900.
- history of Colorado. B. 37:40, 1897; B. 44:154, 1898; B. 56:190, 1900.

Ornithopus sativus. See Serradella.

Orthoptera, Colorado, list. B. 94:17, 1904.

Oryzopsis cuspidata, description and analysis. B. 12:92, 1890.

Oyster-shell—
- bark louse *(Lepidosaphes ulmi)*—
  - description and remedies. B. 114:15, 1906.
  - *See also* Oyster-shell scale.
- scale *(Mytilaspia pomorum)*—
  - description and remedies. B. 47:13, 1898; B. 210:23, 1915; B. 71-11, 1902.

PADDOCK, WENDELL.
- An apricot blight. B. 84, 1903.
- Botanical and horticultural section, Report of. R. 13-21, 1900-1908.
- Crown gall. B. 86, 1903.
- Fruit grower's association. B. 122, 1907.
- Large potato vines and no potatoes. B. 92, 1904.
- Laying down of peach trees. B. 80, 1903.
- New alfalfa disease. P. B. 28, 1906.
- Onion growing in the Cache a la Poudre Valley. B. 81, 1903.
- Plant diseases of 1901. B. 69, 1902.
- Potato failures. P. B. 12, 1902.
- Potato problems. P. B. 26, 1906.
- Pruning of fruit trees. B. 106, 1905.
- Tillage, fertilizers, and shade crops for orchards. B. 142, 1909.
- —and B. O. LONGYEAR.
- Co-operative experiment in tree planting. P. B. 22, 1905.
- The shade trees of Denver. B. 96, 1905.

PADDOCK, WENDELL. (continued)—
  —and ROLFS, F. M.
    Potato failures. P. B. in B. 64 :21, 1901.
Panic grass *(Panicum dichotomum.)* B. 12 :29, 1890.
Panicum—
  capillare. B. 12 :33, 1890.
  crus-galli. See Barn-yard grass.
  dichotomum. See Panic grass.
  glabrum. B. 12 :34, 1890.
  sanguinale. See Crab grass.
  virgatum. See Switch grass.
Parafine-lined vinegar cistern. H. B. Bonebright. P. B. 54, 1910.
Paris green—
  composition. B. 114 :29, 1906.
  dry application. B. 114 :30, 1906.
  notes. B. 71:21, 1902; B. 210 :42, 1915.
PARSHALL, RALPH.
  Irrigation investigations report. R. 31 :37, 1918.
Parsnips. B. 199 :21, 1914; B. 241 :25, 1918.
Paspalum glabrum. B. 12 :91, 1890.
Pasture on college farm, cost. B. 203 : 27. 1914.
Pasture grasses. Leguminous crops. Cantaloupe blight (Arkansas Sub-station.) H. H. Griffin. B. 68, 1902.
Pasturing sheep on alfalfa. Raising early lambs. W. W. Cooke. B. 52, 1899.
PAULL, LESLIE F.
  Delta County fruit investigation. R. 20 :33, 1907.
PAYNE, J. E.
  Advice to plains settlers. P. B. 46, 1907; B. 123:4, 1907.
  Cattle raising on the plains. B. 87, 1904.
  Cow as an assistant. Hints to plains settlers. P. B. 52, 1910.
  Crops for unirrigated lands. P. B. 18, 1903.
  Dairying on the plains. B. 88, 1904.
  Field notes from trips in eastern Colorado. B. 59, 1900.
  Home garden. Hints to plains settlers. P. B. 50, 1910.
  Investigations of the Great Plains. Unirrigated lands of eastern Colorado. Seven years study. B. 77, 1903.
  Notes on dry land orchard. B. 173, 1910.
  Prairie dog as a range pest and and methods of extermination. P. B. 16, 1903.
PAYNE, J. E. (Continued)—
  Report for the Rainbelt Experiment Station. R. 9-12, 1896-1899.
  Russian thistle as forage. P. B. 5. 1900; B. 64 :15, 1901.
  Sod crops. Hints to plains settlers. P. B. 51, 1910.
  Trials of macaroni wheat on dry farming. P. B. 17, 1903.
  Unirrigated alfalfa in upland. B. 90, 1904.
  Wheat raising on the plains. B. 89, 1904.
  Windmill irrigation. Hints to plains settlers. P. B. 53, 1910.
  See Watrous, F. L. jt. author. B. 61, 1900.
Pea—
  culture in the San Luis Valley. B. 209 :20, 1915.
  family characteristics. B. 211 :39, 1915.
  root diseases. B. 69 :14, 1902.
  vine hay. B. 39 :24, 1897.
  weevil *(Bruchus pisi.)* B. 6 :14, 1888; B. 19 :30, 1892; B. 47 :43, 1898.
  See also Peas.
Peach—
  aphis—
    black *(Aphis persicae-niger)*—
      history. B. 133 :37, 1908; B. 134 :12, 1908.
      notes. B. 169 :20, 1910; B. 210 :28, 1915.
      remedies. B. 133:38, 1908.
    green *(Myzus persicae)*—
      food plants. B. 133 :35, 1908.
      history. B. 133 :32, 1908; B. 134 :12, 1908.
      life history. B. 169 :13, 1910.
      notes. B. 210 :27, 1915.
      remedies. B. 133 :36, 1908; B. 134 :12, 1908.
      spraying experiments. B. 169 :15, 1910.
  borer *(Sanninoidea exitiosa)*—
    description and remedies. B. 47:24, 1898; B. 114 :21, 1906; B. 169 :9, 1910.
    life history. B. 119 :11, 1907.
    notes. B. 210 :29, 1915.
    remedies. B. 71 :16, 1902.
  fruit spot control. R. 24 :61, 1911.
  insects injurious to. B. 114 :18, 1906.
  mildew. P. B. 43, 1907.
    effects of. B. 107 :3, 1906.
    notes. B. 118 :9, 1907.
    remedies. B. 107 :5, 1906; B.

Peach (continued)—
  Mildew (continued)—
      212 :32, 1915.
    orchards, laying down of trees. B. 80, 1903.
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Peach mildew. O. B. Whipple. B. 107, 1906.
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      —*(Eriocampoides limacina.)*
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      —*(Selandria cerasi.)*
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      description. B. 218 :7, 1916.
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- Phosphorus compounds in soils. B. 196 :35, 1914.
- *Phoxopteris fragariae.* See Strawberry leaf-roller.
- *Phragmites communis.* See Reed grass.
- *Phthorimaea operculella.* See Potato-tuber moth.
- *Phyllotreta albionica.* See Cabbage flea-beetle, Colorado.
- *Phytoptus.* See Plum-leaf nail-gall.
- *Phytoptus pyri.* See Pear leaf-blister.
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- Pickles shipped into Colorado in 1909. B. 153 :21, 1910.
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  - best breeds for Colorado. B. 146 :5, 1909.
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  - feeding at Colorado Experiment Station. B. 146 :18, 1909.
  - feeding experiments. B. 40 :18, 1897 ; 1900/1, B. 74:24, 1902 ; B. 74 :11, 1902 ; 1906/8. B. 165 1910 ; B. 188 :3, 1913.
  - feeds for. B. 146 :20, 1909.
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  - raising on the plains. P. B. in B. 123 :18, 1907.
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  - sore mouth disease of *(Necrobacillosis.)* B. 137 :3, 1909.
  - small grain vs. corn for. B. 74 :9, 1902.
  - sow, feed and management. B. 146 :13, 1909.
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- Pigs (Continued)—
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- Pine-leaf scale *(Chionaspis pinifoliae.)* remedies. B. 47 :36, 1898.
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    - distribution in Colorado. B. 224 :53, 1917.
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  - pinon *(Pinus edulis. Caryopitys edulis)*—
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  - white western *(Pinus flexilis. Apinus flexilis.)* B. 130 :16, 1908.
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- *Pinus*—
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  - *scopulorum.* See Pines, bull.
- *Pisum arvense.* See Peas, field.
- *Plagiodera scripta.* See Cottonwood leaf beetle.
- Plains lands—
  - acclimated seed. P. B. 34, 1907 ; Same. B. 123 :12, 1907.
  - adobe building. B. 174, 1910.
  - advice to settlers. P. B. 46, 1907 ; Same. B. 123 :4, 1907.
  - cattle raising on. B. 87, 1904 ; B. 189, 1913.
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  seed bed preparation for. P. B. 36, 1907; Same. B. 123 :9, 1907.
  sod crops for. P. B. 51, 1910.
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  vegetation relation to agriculture. B. 224 :35, 1917.
  wheat raising on. B. 89, 1904.
  wind breaks for. P. B. 35, 1907; Same. B. 123 :15, 1907.
  wind mill irirgation. P. B. 53, 1910.

The plains. Some press bulletins. B. 123, 1907.

Plains Sub-station report.
  1900. J. E. Payne. R. 13 :151.
  1901. J. E. Payne. R. 14 :44.
  1902. J. E. Payne. R. 15 :146.
  1903. J. E. Payne. R. 16:33.
  1904. J. B. Robertson. R. 17 :114.
  1905. No report.
  1906. J. B. Robertson. R. 19 :170.
  1907. J. B. Robertson. R. 20 :50.
  1908. J. B. Robertson. R. 21 :29.
  1909. J. B. Robertson. R. 22 :66.
  1910. J. W. Adams. R. 23 :79.
  1911. J. W. Adams. R. 24 :45.
  1912. J. W. Adams. R. 25 :36.
  1913. J. W. Adams. R. 26 :22.
  1914. J. W. Adams. R. 27 :23.
  1915. J. W. Adams. R. 28 :21.
  For earlier report see Rainbelt Experiment Station.
  See also. Dry land specialist.

Plant—
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  lice—
    description. B. 134 :3, 1908.
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    spraying solution for. P. B. 21, 1904.
    See also Apple aphis.

Plant diseases of 1901. Wendell Paddock. B. 69, 1902.

Plant lice and their remedies. S. Arthur Johnson. P. B. 20, 1903.

Plants—
  ash contitutents of. B. 208 :41, 1915.
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  poisonous. B. 137 :5, 1909; B. 211, 1915.
    studies. B. 113:3, 1906.

Platte Valley—
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  rainfall, annual. 1880-1910, B. 180, pt. 1 :45, 1911; B. 180, pt. 3 :146, 1911.
  soil analysis. B. 42 :32, 1898.
  sugar beets. B. 42 :10, 1898.
  water distribution. B. 33 :38, 1896.
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Plowing, dry farming. B. 103 :3, 1905.

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  curculio *(Conotrachelus nenuphar)*—
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- Plums (continued)—
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- Poa—
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- Poisonous plants. See Plants, poisonous.
- *Polypogon monspeliensis.* See Beard grass.
- Poplar tree borer *(Saperda calcarata.)* B. 6 :17, 1888.
- Pork products shipped into Colorado. B. 153 :5, 1910.
- Post, William M. Test in measurement of water applied to field of. B. 22 :16, 1893.
- Potassium compounds in soils. B. 196: 36, 1914.
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    - *Corticum vagum.* B. 92 :3, 1904.
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  - dry rot. B. 243 :31, 1918.
  - flea beetle *(Epitrix cucumeris)*—
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    - San Luis Valley. B. 117 :5, 1907.
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    - worm. R. 6 :55, 1893.
  - seed—
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    - treatment. B. 117 :20, 1907.
  - tuber moth. B. 199 :48, 1914.
- Potato culture in Colorado. E. P. Sandsten. B. 243, 1918.
- Potato failures. W. Paddock and F. M. Rolfs, P. B. 8 in B. 64 :21, 1901.
- Potato failures. W. Paddock. P. B. 12. 1902.
- Potato failures, a preliminary report. F. M. Rolfs. B. 70, 1902.
- Potato failures, a second report. F. M. Rolfs. B. 91, 1904.
- Potato flea beetle. S. Arthur Johnson. P. B. 23, 1904.
- Potato growing in Colorado. E. P. Sandsten. B. 220, 1917.
- Potato industry in Colorado. C. L. Fitch and E. R. Bennett. B. 175, 1910.

- Potato insects. S. Arthur Johnson. B. 175, 1910.
- Potato investigations report.
  - 1906. E. R. Bennett. R. 19:140.
  - 1907. E. R. Bennett. R. 20 :29.
  - 1908. E. R. Bennett. R. 21 :147.
- Potato problems. W. Paddock. P. B. 26, 1906.
- Potato specialist report.
  - 1911. C. L. Fitch. R. 24 :65.
  - 1912. C. L. Fitch. R. 25 :43.
- Potatoes—
  - analyses. B. 7 :17, 1888.
  - botany of. B. 175 :8, 1910.
  - climatic requirements for. B. 220 :4, 1917.
  - cost of production. B. 117 :23, 1907.
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  - grading. B. 220 :18, 1917 ; B. 243 : 16, 1918.
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  - hybridizing. B. 176:12, 1910.
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  - insect pests. B. 117 :15, 1907.
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  - notes. B. 30 :7, 1894 ; B. 199 :23, 1914 ; B. 241 :24, 1918.
  - pearl. B. 176 :3, 1910.
  - planting. B. 175 :28, 1910 ; B. 220:7, 1917 ; B. 243 :12, 1918.
  - root studies. B. 216 :10, 1915.
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- Potatoes (Continued)—
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    - requirements for. B. 220 :4, 1917.
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  - storage. B. 220 :23, 1917 ; B. 243 : 33, 1918.
  - storage house. B. 117:14, 1907.
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  - varieties. B. 4 :4, 1888 ; B. 7 :5, 1888 ; B. 30 :8, 1894 ; B. 117 :9, 1907 ; B. 175 :16, 1910 ; B. 220 :24, 1917 ;B. 243 :17, 1918.
  - wild, crosses. B. 4 :13, 1888.
- Potatoes and sugar beets. J. Cassidy and D. O'Brine. B. 7, 1888.
- Potatoes and tobacco. J. Cassidy. B. 4, 1888.
- Potatoes on the plains, suggestions to new settlers. E. R. Bennett. P. B. 37, 1907 ; Same. B. 123 :14, 1907.
- POTTER, CARL H.
  - Bush fruits, including gooseberries, raspberries, blackberries, and dewberries. B. 60, 1900.
  - A so-called blight cure. P. B. 6, 1900 ; Same. B. 64 :17, 1901.
  - See Crandall, C. S. jt. author. B. 53, 1900.
- Poudre River. See Cache a la Poudre.
- Poultry—
  - best breed of. B. 213 :9, 1915.
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  - mites. B. 185 :8, 1912.
  - parasitic worms of. B. 185 :11, 1912.
  - raising in eastern Colorado. B. 145:11, 1909.
  - shipped into Colorado. B. 153 :9, 1910.
- Poultry raising. W. E. Vaplon. B. 164, 1910.
- Poultry raising in Colorado. W. E. Vaplon. B. 213, 1915.
- Poultry specialist report.
  - 1910. W. E. Vaplon. R. 23 :84.
  - 1911. W. E. Vaplon. R. 24 :73.

Poverty weed *(Iva axillaris.)* B. 23 :9, 1893.

Prairie dog, extermination. P. B. 16, 1903; B. 209 :31, 1915.

Prairie dog as a range pest and methods of extermination. J. E. Payne. P. B. 16, 1903.

Precipitation. See Meteorological observations; Cheyenne Wells; Fort Collins; Grand Junction; Rocky Ford.

A preliminary list of the *Hemiptera* of Colorado. C. P. Gillette and Carl F. Baker. B. 31, 1895.

Preliminary report on the duty of water L. G. Carpenter. B. 22. 1893.

Preliminary report on the fruit interests of the state. C. S Crandall. B. 17, 1891.

Preparation of the seed bed; hints for plains settlers. W. H. Olin. P. B. 36, 1907; Same. B. 123 :9, 1907.

Prionoxistus robiniae. See Cottonwood borer.

Pristiphora grossulariae. See Currant saw-fly.

Productiveness and degeneracy of the Irish potato. C. L. Fitch. B. 176, 1910.

Properties of Colorado wheat. W P. Headden. B. 237, 1918.

Pruning directions. B. 139 :3, 1909.

Pruning fruit trees. Wendell Paddock. B. 106, 1905.

Pruning mature fruit trees. O. B. Whipple. B. 139, 1909.

Pruning locust and catalpa trees for timber. B. O. Longyear. P. B. 41, 1907.

Pseudomonas medicagnis. See Alfalfa stem blight.

Pseudotsuga mucronata. See Fir. Douglas.

Psychrometer. B. 49 :6, 1898.
  registering. B. 49 :8, 1898.

Publications, Editor of, Report of,
  1917. R. L. Crosman. R. 30 :31.
  1918. R. L. Crosman. R. 31 :45.

Puccinia asparagi. See Asparagus rust.

Puffballs. B. 201:12, 1914.

Pulvinaria innumerabilis. See Maple scale, cottony.

Pumpkin, notes. B. 199 :27, 1914.

Putnam scale *(Aspidiotus ancylus)*—
  description and remedies. B. 47 :15, 1898; B. 114 :13, 1906.
  notes. B. 38 :36, 1897; R. 13 :125, 1900.

Pyrethrum, as an insecticide. B. 6 :6, 1888; B. 71 :30, 1902; B. 114 :38, 1906.

Quercus See Scrub oak.

QUICK, WALTER J.
  Agricultural section, Report of. R. 4, 1891.
  The best milk tester for the practical use of the farmer and dairyman. The influence of food upon the pure fat present in milk. B. 20, 1892.
  concerning subjects investigated by the Experiment Station. Special bulletin "A".
  Index bulletin. Indexing the first seventeen bulletins of the station for Volume 1. B. 18, 1891.
  Report of the director. R. 4-5, 1891-92.

Quince—
  rust *(Gymnosporangium)* B. 69 : 18, 1902.
  tree pruning. B. 139 :18, 1909.

Rabies—
  control. B. 162 :8, 1910.
  history. B. 162 :3, 1910.
  nature of. B. 162 :4, 1910.

Rabies. G. H. Glover and B. F. Kaupp. B. 162. 1910.

Radishes. B. 199 :27, 1914; B. 241 :27, 1918.

Rainbelt Experiment Station report.
  1894. J. B. Robertson. R. 7 :70.
  1895. J. B. Robertson. R. 8 :137.
  1896. J. E. Payne. R. 9 :175.
  1897. J. E. Payne. R. 10 :93.
  1898. J. E. Payne. R. 11:203.
  1899. J. E. Payne. R. 12 :52.
  For later reports *see* Plains Substation report.

Rainbelt Experiment Station. Six years work. R. 12 :71, 1899.

Rainfall—
  Cheyenne Wells. P. B. in B. 123 : 31, 1907.
  Denver. P. B. in B. 123 :24, 1907.
  for Colorado. B. 103 :25, 1905; B. 145 :15, 1909.
  Fort Collins. P. B. in B. 123 :25, 1907.
  Hemps. P. B. in B. 123 :27, 1907.
  Le Roy. P. B. in B. 123 :29, 1907.
  Rocky Ford. P. B. in B. 123:30, 1907.
  Wray. P. B. in B. 123 :26, 1907.
  Yuma. P. B. in B. 123 :28, 1907.

Rainfall on the plains. L. G. Carpenter. P. B. in B. 123 :21, 1907.
  See also Meteorological observations.

Raising early lambs. Pasturing sheep on alfalfa. W. W. Cooke. B. 52, 1899.

Raising hogs in Colorado. H. M. Cottrell. B. 146, 1909.

Raising hogs on the plains. H. M. Cottrell. P. B. in B. 123 :18, 1907.

Raspberries—
- black. B. 195 :7, 1914.
- cane treatment. B. 206 :7, 1915.
- cultivation. B. 171 :8, 1910.
- fungous diseases of. B. 212 :43, 1915.
- insects injurious to. B. 210 :35, 1915.
- late frost injuries. B. 206:5, 1915.
- pruning. B. 171 :12, 1910.
- purple-cane, culture. B. 195 :6, 1914.
- red, culture. B. 195 :3, 1914.
- requirements. B. 171 :4, 1910.
- *Sphaerella rubinia* on. B. 206 :12, 1915.
- varieties. B. 17 :41, 1891 ; B. 60 :7, 1900 ; B. 171 :6, 1910.
- winter protection. B. 171 :10, 1910.

Raspberry—
- anthracnose. B. 41:20, 1898 ; B. 171 :16, 1910 ; B. 212 :43, 1915.
- blight, spraying notes. R. 24 :18, 1911.
- cane blight. B. 195 :19, 1914.
- diseases. B. 171:16, 1910.
- saw-fly *(Selandria rubi.)* B. 6 :18, 1888.

Ration experiments with lambs, 1906/7, 1907/8. Self feeders for hay. W. L. Carlyle and G. E. Morton. B. 151, 1900.

Ration experiments with swine 1906-8. W. L. Carlyle and G. E. Morton. B. 165, 1910.

Ration experiments with swine 1908-11. G. E. Morton. B. 188, 1913.

Reclaiming nitre soil in the Grand Valley. E. P. Sandsten. B. 235, 1918.

Red spider. See Spider, red.

Red top grass *(Agrostis vulgaris.)* B. 68 :5, 1902.

REED, JOSEPH.
- Treatment of stinking smut in wheat. B. 79, 1903.

Reed grass *(Phragmites communis.)* B. 12:118, 1890.

REID, L. I.
- Celery growing in Colorado. B. 144, 1909.

REINKING, OTTO A. See Robbins, W. W. B. 212, 1915.

Relation of bovine to human tuberculosis. G. H. Glover. B. 66, 1901.

Report of experiments in apiary. C. Max Brose. B. 5. 1887

Report of experiments in irrigation and meteorology. Elwood Mead. B. 1, 1887.

Report of experiments with grains, grasses, and vegetables. A. E. Blunt. B. 2, 1887.

Reservoirs—
- evaporation from. B. 45 :4, 1898 ; B. 45 :14, 1898.
- loss by seepage from. B. 45 :5, 1898.

Resin soap, washes. B. 71 :29, 1902.

Return waters. See Seepage.

Rex mixture, commercial—
- for Howard scale. B. 120 :14, 1907.

Rhizoctonia—
- potato disease. B. 70 :3, 1902.
  - development. B. 91 :8, 1904.
  - experiments. B. 70 :7, 1902 ; B. 91 :21, 1904.
  - history. B. 91:7, 1904.
  - injuries. B. 91 :11, 1904.
  - remedies. B. 91 :14, 1904. B. 212 :41, 1915.
  - treatment. B. 70 :11, 1902.
- *See also* Blackberry root disease.

Rhopalocera. Colorado. B. 43 :4, 1898.

Rhubarb. B. 199 :28, 1914 ; B. 241 :28, 1918.

Rhus—
- *rydbergii.* See Poison ivy.
- *trilobata.* See Skunk-bush.

Rhyncites bicolor. B. 6 :18, 1888.

Rio Grande River—
- seepage—
  - gains and losses. 1896-1903, B. 180, pt. 1:43, 1911 ; B. 180, pt. 3 :144, 1911.
  - measurement. R. 11 :193, 1898 ; R. 13 :139, 1900.
- water analysis. B. 230 :8, 1917 ; 1898-1902, B. 180, pt. 3:120, 1911.

Rio Grande Valley—
- alkali. B. 230 :16, 1917.
- canal seepage. B. 48 :12, 1898.
- description of water resources. B. 180, pt. 1 :9, 1911.

Roads, construction costs. P. B. 29, 1907.

ROBBINS, WILFRED W.
- Algae in some Colorado soils. B. 184, 1912.
- Botanical section, Report of. R. 28 :31, 1915-1918.

- Robbins, Wilfred W. (Continued)—
  - Native vegetation and climate of Colorado in their relation to agriculture. B. 224, 1917.
  - —and Eggington, G. E.
  - Alfalfa dodder in Colorado. B. 248, 1918.
  - —and Reinking, Otto A.
  - Fungous diseases of Colorado crop plants. B. 212, 1915.
  - —and Vasey, H. E. and Eggington, G. E.
  - Cleaned, treated, and tested seed for Colorado. B. 238, 1918.
  - See Glover, G. H. jt. author. B. 211, 1915; B. 246, 1918.
- Robertson, J. B.
  - Plains Sub-station report. R. 17-22, 1904-1909.
  - Rain-belt Experiment Station report. R. 7-8, 1894-1895.
- Rocky Ford—
  - Cantaloupe industry history. B. 108, 1906.
  - melon's grower's association development. B. 108 :6, 1906.
  - meteorological observations. R. 15 :194, 1902.
  - precipitation. 1888-1911, B. 182 :42, 1912; 1888-1917, B. 245 :44, 1918.
  - temperature. 1888-1911, B. 182 :40, 1912; 1888-1917, B. 245 :41, 1918.
- Rodents, methods of extermination. B. 209 :31, 1915.
- Rolfs, F. M.
  - Potato failures, a preliminary report, B. 70, 1902.
  - Potato failures, a second report. B. 91, 1904.
  - See Paddock, Wendell. jt. author. P. B. in B. 64 :21, 1901.
- Root—
  - gall. B. 195 :18, 1914.
  - rots. B. 118 :10, 1907.
- Roses, insects injurious to. B. 210 :40, 1915.
- Rubber plant *(Hymenoxys floribunda)*—
  - effect on live stock. B. 113 :22, 1906.
  - Colorado, poisoning. B. 211 :68, 1915.
- Russian thistle—
  - analysis. B. 135 :15, 1908.
  - feeding value. P. B. 5, 1900; Same. B. 64 :15, 1901.
  - notes. B. 135 :15, 1908; B. 28, 1894.
- Russian thistle as a forage crop. J. E. Payne. P. B. 5, 1900; Same. B. 64: 15, 1901.
- Rust-resisting; cantaloupe. Philo K. Blinn. B. 104, 1905.
- Rusts—
  - poisoning in animals. B. 211 :10, 1915.
- Rusty brown plum louse. See Plum aphis, rusty brown.
- Rydberg, F. A.
  - Flora of Colorado. B. 100, 1905.
- Rye—
  - culture, San Luis Valley. B. 209 : 28, 1915.
  - experiments. B. 2 :12, 1887.
  - grass *(Lolium perenne.)* B. 12 :44, 1890.
    - giant *(Elymus condensatus.)* B. 12 :54, 1890.
    - Italian. B. 12 :109, 1890.
  - smut control. B. 238 :30, 1918.
- *Sabina.* See Cedar, red.
- Sackett, Walter G.
  - Ammonifying efficiency of certain Colorado soils. B. 184, 1912.
  - A bacterial disease of alfalfa. B. 158, 1910.
  - Bacterial stem blight of field and garden peas. B. 218, 1916.
  - Bacteriological section, Report of R. 21 :31, 1908-1918.
  - Bacteriological studies of the fixation of nitrogen in certain Colorado soils. B. 179, 1911.
  - Butter making. Clean milk and commercial starters. B. 156, 1910.
  - Comparative bacteriological study of the water supply of the city and county of Denver, Colorado, B. 225, 1917.
  - Hold-over blight in the pear. B. 177, 1911.
  - Home-made cider vinegar. B. 192, 1913.
  - A new alfalfa disease, stem blight. (An abbreviated edition of bulletin 158.) B. 159, 1910.
  - Nitrifying efficiency of certain Colorado soils. B. 193, 1914.
  - Some bacterial diseases of plants. B. 138, 1909.
  - Some soil changes produced by micro-organisms. B. 196, 1914.
  - Spur blight of the red raspberry caused by *Sphaerella rubina.* B. 206, 1915.
  - See Kezer, Alvin. jt. author. B. 226, 1917; B. 234, 1918.
- Sage, poisoning by. B. 211 :67, 1915.

- Sagebrush—
  - agriculture in region of. B. 224:42, 1917.
  - distribution in Colorado. Map. B. 224:38, 1917.
- St. Vrain Creek—
  - seepage—
    - gains and losses. 1898-1910, B. 180, pt. 3:138, 1911; 1898-1910, B. 180, pt. 1:37, 1911.
    - measurement. 1898-99, R. 12:44, 1899; 1900, R. 13:137, 1900.
  - water—
    - analysis. B. 82:60, 1903.
    - measurement. 1898-1910, B. 180, pt. 3:20, 1911.
- Salsify. B. 172:11, 1910; B. 199:25, 1914.
- Saltbush *(Atriplex argentea)*—
  - analysis. B. 124:61, 1907.
  - Australian—
    - ash analysis. B. 135:13, 1908.
    - composition. B. 135:8, 1906
    - digestibility. B. 135. 1908.
  - calorific value. B. 124:66, 1907.
  - coefficient of digestion B. 124:64, 1907.
  - digestibility. B. 93:36, 1904.
  - furfurol in. B. 124:72, 1907.
  - methoxyl in. B. 124:66, 1907.
- Salt grass *(Distichlis maritima)*—
  - description and analysis. B. 12:105, 1890.
- San Jose Scale *(Aspidiotus perniciosus)*—
  - description. B. 114:13, 1906.
  - notes. B. 38:34, 1897; P. B. 48, 1909; B. 210:10, 1915.
  - remedies. B. 47:14, 1898; B. 71:11, 1902.
- San Jose scale. C. P. Gillette. P. B. 48, 1909.
- San Luis Lake, water analysis. B. 230:39, 1917.
- San Luis Valley—
  - black alkali in. B. 231, 1917.
  - canal seepage. B. 48:9, 1898.
  - climate. B. 209:4, 1915.
  - farming conditions. B. 209:11, 1915.
  - hog cholera control in. B. 197:6, 1914.
  - irrigation in. B. 209:8, 1915.
  - location and topography. B. 209:3, 1915.
  - rainfall, annual. 1880-1910, B. 180, pt. 1:45, 1911; 1880-1910, B. 180, pt. 3:146, 1911.
  - soil analysis. B. 42:34, 1898.
  - soils. B. 209:5, 1915.
  - sub-irrigation B. 231:3, 1917.
  - sugar beets in. B. 42:14, 1898.
  - water conditions in. B. 230:3, 1917.
- San Luis Valley Experiment Station.
  - meteorological observations. 1890, R. 3:154, 1890; R. 4:96, 1891.
  - Report.
    - 1888. H. H. Griffin. R. 1:237.
    - 1889. H. H. Griffin. R. 2:88.
    - 1890. H. H. Griffin. R. 3:184.
    - 1891. M. E. Bashor. R. 4:102.
    - 1892. M. E. Bashor. R. 5:55.
    - 1893. Frank Beach. R. 6:72.
    - 1894. C. A. Duncan. R. 7:79.
    - 1895. C. A. Duncan. R. 8:153.
    - 1896. C. A. Duncan. R. 9:155.
- Sand-bur—
  - *(Cenchrus tribuloides.)* B. 12:117, 1890; B. 211:19, 1915.
  - *(Solanum restratum)* B. 211:62, 1915.
- SANDSTEN, E. P.
  - Horticultural section, Report of. R. 26-31, 1913-1918.
  - Potato culture in Colorado. B. 243, 1918.
  - Potato growing in Colorado. B. 220, 1917.
  - Reclaiming soil in the Grand Valley. B. 235, 1918.
  - Small fruits for Colorado. B. 195, 1914.
  - and LIMBOCKER, T. F. and MCGINTY, R. A.
  - Fruit survey of Mesa County. B. 223. 1917.
- Sandwick. See Vetch, hairy.
- *Sannina exitiosa.* See Peach borer.
- *Saperda calcarata* See Poplar tree borer.
- *Saponaria vaccaris.* See Cow cockle.
- *Sarcobatus vermiculatus.* See Greaswood.
- Saw fly—
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- *Schedonnardus texanus* B. 12:122, 1890.
- Scheele's green. B. 71:23, 1902; B. 114:31, 1906.
- *Schizoneura*—
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  - *lanigera.* See Aphis, wooly.
- Scrub oak *(Quercus)*—
  - non-poisonous to cattle. B. 211:27, 1915.
- Scurfy scale *(Chionaspis furfurus)*—
  - description and remedies. B. 47:12, 1898; B. 71:11, 1902; B. 114:14, 1906.
  - notes. B. 210:23, 1915.
- Scurvy bark louse See Scurfy scale.

Seed—
- acclimated. P. B. 34, 1907; Same. B. 123 :12, 1907.
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- cleaned, need for. B. 238 :3. 1918.
- formalin treatment for smut. P. B. 24, 1906.
- germination test. B. 238 :15, 1918.
- pure, need for. B. 238 :3, 1918.
- purity test. B. 238 :13, 1918.
- testing, home method of. B. 238 :13, 1918.
- treatment for prevention of disease. B. 238 :20, 1918.

Seed law, Colorado. B. 238:32, 1918.

Seeding field peas. W. H. Olin. P. B. 40, 1907

Seeding, tillage, and irrigation. Fred A. Huntley. B. 26 :25, 1894.

Seepage—
- Boulder Creek. P. B. 14, 1902.
- Cache a la Poudre Valley. 1891-92, R. 4 :45, 1891; B. 33 :37, 1896; B. 48:7, 1898; B. 82 :53, 1903.
- effect of soil temperature. B. 33 :43, 1896.
- Fort Morgan Canal. B. 48 :15, 1898.
- gains in canals. B. 48, 1898.
- general condition of. B. 180, pt. 1 :46, 1911.
- investigations. B. 33, 1896.
- laws of flow of. B. 180, pt. 1 :61, 1911.
- lessening of. B. 48 :27, 1898.
- losses from reservoirs by. B. 45:5, 1898.
- losses in canals from. B. 48, 1898
- losses in different formations. B. 48 :30, 1898.
- measurement. B. 33 :6, 1896; B. 180, pt. 1 :33, 1911.
  - territory covered by. P. B. 7 in B. 64 :19, 1901.
- mountain. B. 180, pt. 1 :64, 1911.
- Platte Valley B. 33 :28, 1896.
- rate of flow B. 33 :44, 1896.
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- Rio Grande Valley. B. 48 :12, 1898.
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- sources of increase. B. 33 :50, 1896.
- South Boulder Creek. P. B. 14, 1902.
- Uncompahgre River. P.B. 15, 1902.
- variation with depths of water. B. 48 :25, 1898.
- *See also* Arkansas River; Bear Creek; Big Thompson River; Boulder Creek; Cache a la Poudre River; Clear Creek; Left Hand Creek; Little Thompson River; Rio Grande River; St. Vrain Creek; Uncompahgre River.

Seepage and return waters. General discussion. L. G. Carpenter. B. 180, pt. 1. 1911.

Seepage and return waters. Detailed measurements. The Cache a la Poudre River. L. G. Carpenter. B. 180, pt. 2. 1911

Seepage and return waters. Detailed measurements. L. G. Carpenter. B. 180, pt. 3, 1911.

Seepage measurement of the Experiment Station. L. G. Carpenter. P. B. 7 in B. 64 :19, 1901.

Seepage or return waters from irrigation L. G. Carpenter. B. 33, 1896.

Seepage or return waters on Boulder and South Boulder creeks. L. G. Carpenter. P. B. 14, 1902.

Seepage or return waters on the Uncompahgre River. L. G. Carpenter. P. B. 15, 1902.

Selandria—
- *cerasi.* See Pear slug.
- *rubi* See Raspberry saw-fly.

Serradella *(Orinthopus sativus.)* B. 68 :7, 1902.

Sesia tipuliformis. See Currant borer, imported.

Setaria—
- *glauca.* B. 12 :104, 1890.
- *italica.* B. 12 :105, 1890.
- *viridis.* B. 12:104, 1890.

Shade trees. See Trees, shade.

The shade trees of Denver. W. Paddock and B. O. Longyear. B. 96, 1905.

Sheep—
- dip—
  - experiments. B. 38 :11, 1897.
  - formulas for. B. 38 :7, 1897.
- feeding. B. 32 :6, 1895.
  - cost. B. 32 :28, 1895.
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  - methods. B. 32 :22, 1895.
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- raising early lambs. B. 52 :24, 1899.
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    treatment. B. 38 :7, 1897.
  varieties. B. 32 :6, 1895.
Sheep feeding in Colorado. W. W. Cooke. B. 32, 1895.
Sheep scab. A few insect enemies of the orchard. C. P. Gillette. B. 38, 1897.
Shelter belts for the plains. P. B. 35, 1907; Same. B. 123 :15, 1907.
Shepherd's purse *(Capsella bursa-pasteris.)* B. 23 :7, 1893.
Short's milk test. B. 20 :4, 1892.
Shot-hole—
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  for beef cattle. B. 200 :31, 1914.
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  types used in Colorado. B. 200:10, 1914.
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Silos and silage in Colorado. H. E. Dvorachek. B. 200, 1914.
Siphons, loss of head of water flowing thru. B. 194 :32. 1914.
Skunk-bush. *(Rhus trilobata.)* B. 211 : 51, 1915.
Small fruits for Colorado. E. P. Sandsten. B. 195, 1914.
Smith, S. Van.
  Cabbage breeding experiments report. R. 24-25, 1911-1912.
Smut—
  formalin treatment of grain seed for. P. B. 24, 1906.
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    description. B. 242 :8, 1918.
  poisoning in animals. B. 211 :9, 1915.
  treatment of seed grain for. P. B. 49, 1909.
Sneezeweed, poisoning by. B. 211 :66, 1915.
Snow's effect on stream flow. B. 55, 1901.
Snow-on-the-mountain *(Euphorbia marginata.)* B. 211:49, 1915.
Snowball louse. R. 15 :107, 1902.
So-called blight cure. Carl H. Potter P. B. 6, 1900; Same. B. 64 :17, 1901.
Soap as an insecticide B. 71 :26, 1902; B. 114 :34, 1906; B. 210 :45, 1915.
Sod crops. Hints to plains settlers. J. E. Payne. P. B. 51, 1910.
Soil—
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  bacteria—
    distribution. B. 196 :7, 1914.
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    greenhouse studies. B. 216 :15, 1915.
    Longmont. 1910-11, B. 216 :6, 1915.
    studies. B. 216:5, 1915.
    See also Meteorological observations.
A soil study. Part 1. The crop grown; sugar beets. W. P. Headden. B. 46, 1898.

A soil study. Part 2. The crop grown; sugar beets. W. P. Headden. B. 58, 1900.

A soil study Part 3. The soil. W. P. Headden. B. 65, 1901.

A soil study. Part 4. The ground water. W. P. Headden. B. 72, 1902.

Soils—
- acid soluble in. B. 65 :31, 1901.
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  - analysis. B. 9 :19, 1889; B. 65 :6, 1901.
  - composition in Colorado. B. 183 :5, 1912.
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  - bacteriological studies. B. 179, 1911.
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- water's effect on. B. 65:22, 1901.
- water soluble in. B. 65 :32, 1901.
- wheat. B. 89 :28, 1904.

Soils and alkali. D. O'Brine. B. 9, 1889.

Solanum rostratum. See Buffalo-bur.

Solar radiation. See Meteorological observations.

Some animal diseases. G. H. Glover, C. L. Barnes and B. F. Kaupp. B. 137, 1909.

Some bacterial diseases of plants. Walter G. Sackett. B. 138, 1909.

Some Colorado grasses and their chemical analysis. J. Cassidy and D. O'Brine. B. 12, 1890.

Some Colorado mushrooms. B. O. Longyear. B. 201, 1914.

Some insects and mites attacking the peach in Colorado. G. P. Weldon. B. 169, 1910.

Some new Colorado *Orthoptera.* Lawrence Bruner. B. 94, 1904.

Some of the more important insects of 1903, and an annotated list of Colorado *Orthoptera.* C. P. Gillette. B. 94, 1904.

Some poultry diseases. B. F. Kaupp. B. 185, 1912.

Some soil changes produced by microorganisms. Walter G. Sackett. B. 196, 1914.

Sorghum—
- fodder—
  - analysis. B. 124 :56, 1907.
  - Calorific value. B. 124 :60, 1907.
  - coefficient of digestion. B. 124 : 58, 1907.
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Spider, red *(Tetranychus bimaculatus)*—
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Spotted bean beetle. See Bean-beetle, spotted.
Spray mixtures for Howard scale. B. 120 :12, 1907.
Spraying apparatus, description. B. 15 :14, 1891.
Spraying for codling moth, some points to be considered. C. P. Gillette. P. B. 44, 1907.
Spraying for plant lice and the codling moth. C. P. Gillette. P. B. 21, 1904
Spring grain-louse. C. P. Gillette. P. B. 45, 1907.
Spruces—
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    rotation. B. 140 :8, 1909.
    varieties. R. 2 :27, 1889 ; B. 17:41, 1891 ; B. 29 :8, 1894 ; B. 53 :8, 1900 ; B. 140 :9, 1909.
Strawberries. C. S. Crandall and C. H. Potter. B. 53, 1900.
Strawberries and grapes M. J. Huffington. B. 29, 1894.
Strawberry—
    crown borer *(Tyloderma fragariae)*—
        description and remedies. B. 114:27, 1906 ; B. 71 :19, 1902.
        notes. B. 210 :35, 1915.
    insects injurious to. B. 114 :26, 1906.
    leaf blight *(Sphaerella fragariae.)* B. 69 :20, 1902 ; B. 212 :46, 1915.
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        (Phoxopteris comptana.) R. 10 :58, 1897.
        (Phoxopteris fragariae.) B. 47 : 27, 1898 ; B. 71 :19, 1902.
    saw-fly, western. R. 15 :113, 1902.
Strawberry growing in Colorado. B. O. Longyear. B. 140, 1909.
Streams—
    effect on melting. B. 55 :6, 1901.
    general flow of. B. 55 :4, 1901.
    relation to forests. B. 55, 1901.
Studies of health in potatoes. C. L. Fitch. B. 216, 1915.
A study of alfalfa and some other hays. W. P. Headden. B. 39, 1897.
A study of Colorado wheat. Part 1, W. P. Headden. B. 208, 1915.
A study of Colorado wheat. Part 2. W. P. Headden. B. 217, 1916.
A study of Colorado wheat. Part 3. W. P. Headden. B. 219, 1916.
A study of Colorado wheat. Part 4. W. P. Headden. B. 244, 1918.
A study of Colorado wheat, a resume of bulletins 205, 208, 217, 219, 237, 244. W. P. Headden. B. 247, 1918.
Sub-irrigation—
    experiments. B. 240:10, 1918.
    cost. B. 240 :8, 1918.
Subjects investigated by the Experiment Station. Spec. B. "A", 1892.
Sugar-beet—
    caterpillar, remedies. P. B. 1 in B. 64 :4, 1901.
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    leaf-beetle *(Monoxia puncticollis.)* R. 15 :108, 1902.
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    web-worm. See Beet web-worm.
The sugar-beet caterpillar. C. P. Gillette. P. B. 1 in B. 64 :4, 1901.
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    analysis. B. 7 :22, 1888 ; B. 11 :10, 1890 ; B. 14 :11, 1891 ; B. 36 :13, 1897 ; B. 51 :30, 1899.
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  - summary of publications on. B. 63 :4, 1901.
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  - time of ripening. B. 42 :18, 1898.
  - varieties. B. 7 :21, 1888 ; B. 26 :7, 1894 ; B. 51 :17, 1899 ; B. 57 :37, 1900.
- Sugar beets. C. L. Ingersoll and D. O'Brine. B. 11, 1890.
- Sugar beets. D. O'Brine. B. 14, 1891.
- Sugar beets. W. W. Cooke. B. 36, 1897.
- Sugar beets. Irish potatoes. Fruit raising. F. L. Watrous. B. 21, 1892.
- Sugar beets, a resume of the work done by the Experiment Station. W. P. Headden. B. 63, 1901.
- Sugar beets for fattening steers. Carrying range steers through the winter. W. L. Carlyle and G. E. Morton. B. 149, 1909.
- Sugar beets in Colorado in 1897. W. W. Cooke and W. P. Headden. B. 42, 1898.
- Sugar beets in Colorado in 1898. W. W. Cooke. B. 51, 1899.
- Sulphate of ammonia, nitrification in soils. B. 193 :23, 1914 ; Same. B. 193:32, 1914.
- Sulphur—
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  - compounds in soils. B. 196 :37, 1914.
- Sumac. B. 211 :49, 1915.
- Summer culture to conserve moisture. W. H. Olin. P. B. 39, 1907. Same. B. 123:10, 1907.
- Sunshine—
  - Colorado compared to other states. B. 224 :27, 1917.
  - Fort Collins. 1888, R. 1 :216, 1888 ; 1889, R. 2 :64, 1889 ; 1890, R. 3: 104, 1890 ; 1891, R. 4 :59, 1891 ; B. 49 :66, 1898 ; 1897-98, P. B. 2, 1900 ;

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  - Fort Collins (Continued)—
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- Sunshine for 1900. L. G. Carpenter. P. B. 9 in B, 64 :23, 1901.
- Swamp laurel *(Kalmia polifolia.)* B. 211 :56. 1915.
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  - clover aphis *(Aphis medicagnis.)* B. 133 :32, 1908
  - Clover on plains lands. B. 214 :20, 1915.
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  - peas, insects injurious to. B. 210 : 41. 1915.
  - potatoes. B. 199 :31, 1914.
- Swine—
  - feeding experiments. B. 188, 1913.
  - *See also* Pigs.
- Swine feeding in Colorado. Beet pulp and sugar beets for fattening hogs. Home grown grain vs. corn for fattening hogs. Other trials with corn, barley, alfalfa, and beets. B. C. Buffum and C. J. Griffith. B. 74, 1902.
- Switch grass, analysis. B. 12 :30, 1890.
- *Systena*—
  - *mitis* B. 6 :18, 1888.
  - *taeniata* See Flea-beetle, striped.
- Tankage—
  - for pigs. B. 188 :5, 1913.
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- Tarnished plant bug. B. 210 :27, 1915.
- TAYLOR, ESTES PARK.
  - Entomologist, field, Report. R. 19. 1906.
  - Howard scale. B. 120, 1907.
  - Howard scale. P. B. 30, 1907.
  - Western slope fruit investigations, 1906. Report of the field entomologist. B. 119, 1907.
  - Western slope fruit investigation. Condensed report of the field entomologist, 1906. P. B. 42, 1907.
  - See Gillette, C. P. jt. author. B. 133, 1908; B. 134, 1908.
- Temperature, Colorado—
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  - *See also* Meteorological observations.
- Tent caterpillar. B. 210 :13, 1915.
  - *(Clisiocampa fragilis.)* B. 47:7, 1898; B. 71 :8, 1902.
  - *(Malacosoma fragilis)* B. 114 :8, 1906.
- Terrell grass. See *Elymus canadensis*
- Terrestrial radiation. See Meteorological observations.
- Testing and handling of milk and cream. R. McCann. B. 202, 1914.
- *Tetranychus bimaculatus* See Spider, red.
- *Tetraopes femoratus.* See Milkweed beetle.
- *Thamnonoma.* See Currant span-worm; Gooseberry span-worm.
  - *flavicaria.* See Currant span-worm; Gooseberry span-worm.
  - 4-*linearia.* See Currant span-worm; Gooseberry span-worm.
- Thermograph, description. B. 49 :7, 1898.
- Thermometer—
  - Draper's self recording. R. 1 :155, 1888.
  - radiation, description. B. 49 :12, 1898.
  - soil. R. 1 :162, 1888. B. 49 :15, 1898.
  - sun, description. R. 1 :158, 1888.
- *Thermopsis.* See Buckbean.
- Thinning the winesap. Winter and frost injuries of fruit trees. R. S. Herrick. B. 170, 1910.
- Thistle, Russian—
  - eradication. B. 28 :10, 1894.
  - history. B. 28 :3, 1894.
- Thompson, Big. See Big Thompson.
- Thompson, Little. See Little Thompson.
- Thorough tillage system for the plains of Colorado. W. H. Olin. B. 103, 1905.
- *Thrips striatus.* See Onion thrips.
- Tillage, fertilizers, and shade crops for orchards. Wendell Paddock. B. 142, 1909.
- Tillage methods for dry farming. B. 103 :3, 1905.
- *Tilletia faetens.* See Wheat, stinking smut.
- Timber claims in eastern Colorado. B. 59 :6, 1900.
- Timothy *(Phleum pratense)*—
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- burning quality. B. 10 :11, 1890.
- culture. B. 10 :5, 1890; R. 1 :58, 1888.
- varieties. B. 4:16, 1888; B. 10 :12, 1890.

Tobacco. J. Cassidy and D. O'Brine. B. 10, 1890.

Tomato, blight. B. 138 :19, 1909.

Tomato industry of the Arkansas Valley. H. H. Griffin. B. 78, 1903.

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- culture. B. 78 :17, 1903.
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- fungous diseases of. B. 212 :46, 1915.
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- varieties. B. 26 :12, 1894; B. 30 :27, 1894; B. 78 :16, 1903.

Top working fruit trees. O. B. Whipple. B. 147, 1909.

Tortrix roseana. B. 6 :17, 1888.

Toxoptera graminum. See Grain-louse.

Treatment of seed grain to prevent smut. Alvin Keyser. P. B. 49, 1909.

Treatment of stinking smut in wheat. Joseph Reed. B. 79, 1903.

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- crickets *(Oecanthus)*—
  - description and remedies. B. 71 :17, 1902; B. 114 :22, 1906.
- planting, co-operative. P. B. 22, 1905; P. B. 25, 1906.

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- young, handling. B. 106 :3, 1905; B. 118 :14, 1907.
- Trials of macaroni wheat by dry farming. J. E. Payne. P. B. 17, 1903.

Trifolium—
- *eriocephalum.* B. 12:125, 1890.
- *pratense.* See Clover, red.

TRIMBLE, ROBERT E.
- Colorado climatology. B. 182, 1912.
- Colorado climatology. B. 245, 1918.
- See Carpenter, L. G. jt. author. B. 49, 1898; B. 127, 1908.
- See Cone, V M. jt. author. B. 194, 1914.

Trisetum subspicatum. B. 12 :84, 1890.

Trypeta canadensis. See Gooseberry fruit-fly.

Tuberculin test of the college herd. B. C. Buffum. B. 66, 1901.

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- bovine—
  - more virulent than human. B. 66 :10, 1901.
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- cows natural harbinger. B. 66 :10, 1901.
- transmissibility. B. 66 :5, 1901.

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Turpentine, as an insecticide. B. 71 :28, 1902; B. 114:37, 1906; B. 210 :47, 1915.

Two insect pests, the codling moth and the grape-vine leaf-hopper. C. P. Gillette. B. 15, 1891.

Two plant lice of the peach. C. P. Gillette and G. P. Weldon. B. 169, 1910.

Tyloderma fragariae. See Strawberry crown borer.

Types of milling wheat for the plains. W. H. Olin. P. B. in B. 123; 20, 1907.

Typhlocyba—
- *comes* See Grape leaf-hopper.
- *vitifex.* See Grape-vine leaf-hopper.

Two common orchard mites, the brown mite and the red spider. G. P. Weldon. B. 152, 1910.

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      - measurement. R. 13 :140, 1900.
    - water, measurement. 1900-2, B. 180, pt. 3 :131, 1911.
  - Valley, water resources. B. 180, pt. 1 :20, 1911.
- Unirrigated alfalfa on upland. J. E. Payne. B. 90, 1904.
- Unirrigated lands of eastern Colorado. Seven years study. J. E. Payne. B. 77, 1903.
- Unirrigated lands. See Dry farming.
- *Vanessa antiopa.* See Elm-leaf caterpillar.
- VAPLON, W. E.
  - Poultry raising. B. 164, 1910.
  - Poultry raising in Colorado. B. 213, 1915.
  - Poultry specialist report. R. 23-24, 1910-11.
- Variation studies in brome grass, a preliminary report. Alvin Keyser. B. 190, 1913.
- VASEY, HARVEY E.
  - Millet smuts and their control. B. 242, 1918.
  - See Robbins, W. W. jt. author. B. 238, 1918.
- Vegetable growing in Colorado. R. A. McGinty. B. 199, 1914.
- Vegetables—
  - garden planning. B. 241 :3, 1918.
  - harvesting. B. 232 :3, 1917.
  - notes. B. 2:3, 1887; R. 1 :99, 1888; R. 2:31, 1889.
  - seed, planting table. B. 241 :7, 1918.
  - storing. B. 232 :4, 1917; B. 241 :33, 1918.
- *Vertrum speciosum* See Hellebore, white.
- Vetch *(Sandwick.)*
  - hairy *(Vicia villosa.)* B. 26 :3, 1894; B. 68 :9, 1902.
  - on plains lands. B. 214 :23, 1915.
- Veterinary department, work. B. 5:7, 1887.
- Veterinary section, Report of.
  - 1888. W. McEachran. R. 1 :223.
  - 1889. W. McEachran. R. 2 :77.
  - 1904. G. H. Glover. R. 17 :106.
  - 1905. G. H. Glover. R. 18 :51.
  - 1906. G. H. Glover. R. 19 :164.
  - 1907. G. H. Glover. R. 20 :43.
- Veterinary section, Report of. (Continued)—
  - 1908. G. H. Glover. R. 21 :24.
  - 1909. G. H. Glover. R. 22:45.
  - 1910. G. H. Glover. R. 23 :105.
  - 1911. G. H. Glover. R. 24 :74.
  - 1912. G. H. Glover. R. 25 :45.
  - 1913. G. H. Glover. R. 26 :14.
  - 1914. G. H. Glover R. 27 :15.
  - 1915. G. H. Glover. R. 28 :26.
  - 1916. G. H. Glover. R. 29 :36.
  - 1917. G. H. Glover. R. 30:30.
  - 1918. G. H. Glover. R. 31 :43.
- Veterinary pathologist report. 1918. I. E. Newsom. R. 31 :42.
- *Vicia villosa.* See Vetch, hairy.
- *Vigna catjung.* See Cowpea.
- Villoresi canale. B. 13 :25, 1890.
- Vinegar—
  - cider—
    - acetic acid fermentation. B. 192 :11, 1913.
    - alcoholic fermentation. B. 192 : 9, 1913.
    - apple juice, analysis. B. 192 :7, 1913.
    - apple, selection for. B. 192 :5, 1913.
    - clarification of. B. 192:13, 1913.
    - home made. B. 192, 1913.
    - pure culture for. B. 192 :13, 1913.
    - storage. B. 192 :8, 1913.
  - cistern, parafine-lined. P. B. 54, 1910.
- Virginia creeper, insects injurious to. B. 210 :40, 1915.
- Warren's Lake, Fort Collins, water analysis. B. 82 :23, 1903.
- Water—
  - capillary action in soils. B. 103 :18, 1905.
  - changes due to bed and storage. B. 83 :5, 1903.
  - commissioners, powers and duties. B. 67 :8, 1901.
  - computation by Kutter's formula. B. 150 :37, 1909.
  - current meter methods, comparison. B. 194 :43, 1914.
  - distribution of. B. 67 1901; B. 67 :5, 1901.
  - division. B. 13, 1890; B. 27, 1894; B. 150, 1909.
    - time method of. B. 150 :17, 1909.
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  - duty of. B. 22 :5, 1893.
  - flood, matter carried on. B. 82 :65, 1903.
  - flow, laws of. B. 180, pt. 1 :61, 1911.

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  grass *(Beckmannia erucaeformis.)* B. 12:122, 1890.
  ground—
    ammonia in. B. 72:42, 1902.
    chlorin in. B. 72:18, 1902.
    discussion. B. 72:1, 1902.
    lithia in. B. 72:34, 1902.
    nitrates in. B. 72:34, 1902.
    nitrous acid in. B. 72:41, 1902.
    solids in. B. 72:9, 1902; B. 72:20, 1902. Tables.
  hemlock *(Cicuta occidentalis)*—
    poisoning. B. 113:20, 1906; B. 211:52, 1915.
    treatment. B. 113:21, 1906.
  inch, definition. B. 207:3, 1915.
  irrigation—
    effect on lands. B. 83, 1903.
    salts contained in. B. 83:7, 1903.
  level discussion. B. 72:6, 1902.
  losses by seepage and evaporation. B. 45, 1898.
  measurement. B. 1:6, 1887; B. 13, 1890; B. 27, 1894; B. 150, 1909.
    Azusa hydrant for. B. 207:12, 1915.
    Dethridge meter. B. 215:3, 1915.
    divisors. B. 228:3, 1917.
    hydraulic equivalent for. B. 207:16, 1915.
    miner's inch devices tables. B. 207:9, 1915.
    on field of J. H. McClelland. B. 22:10, 1893.
    statute inch devices. B. 207:4, 1915.
    Uncompahgre orifice for. B. 207:10, 1915.
    units of. B. 207:16, 1915.
  mountain. B. 239:42, 1918.
  river—
    changes due to bed of stream. B. 82:17, 1903.
    changes due to irrigation. B. 82:28, 1903.
  changes due to storage. B. 82:18, 1903.
    fertilizing value of. B. 82:26, 1903.
  supply, Denver. See Denver water supply.
  well, analysis. B. 72:23, 1902.
Water, Duty of. L. G. Carpenter. B. 22, 1893.
Water, Measurement and division of. L. G. Carpenter. B. 13, 1890.
Water, Measurement and division of. L. G. Carpenter. B. 27, 1894.
Water, Measurement and division of. L. G. Carpenter. B. 150, 1909.
Watermelons. B. 199:34, 1914.
Waters of the Rio Grande, a contribution to the hydrology of the San Luis Valley, Colorado. W. P. Headden. B. 230, 1917.
Waterways, artificial—
  frictional resistance in. B. 194, 1914.
    as related to current meter methods. B. 194:39, 1914.
    variation in hydraulic factors. B. 194:38, 1914.
WATROUS, FRANK.
  Arkansas Valley Experiment Station report. R. 1-4, 1888-91.
  Sugar beets. Irish potatoes. Fruit raising. B. 21, 1892.
  —and GRIFFIN, H. H. and J. E. PAYNE.
  Bromus inermis. B. 61, 1900.
  See Cooke, W. W. jt. author. B. 26, 1894; B. 30, 1894.
Webworm, sugar beet. See Beet, webworm.
Weeds—
  Colorado. B. 23, 1893.
  poisonous. See Plants, poisonous.
Weir—
  construction and use. B. 13:20, 1890; B. 13:15, 1890; B. 27:20, 1894.
  discharge tables. B. 13:31, 1890; B. 27:36, 1894.
  experiments. B. 13:24, 1890.
  Francis' experiment. B. 13:24, 1894; B. 150:25, 1909.
  modules. B. 13:18, 1890; B. 27:23, 1894; B. 150:22, 1909.
  rectangular. B. 13:23, 1890; B. 27:30, 1894.
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  trapzoidal. B. 27:30, 1894.
  triangular. B. 27:35, 1894; B. 150:35, 1909.
  water discharge. B. 150:43, 1909.
WELDON, GEORGE P.
  Entomologist, field, Report of. R. 21-24, 1908-1911.
  Some insects and mites attacking the peach in Colorado. B. 169, 1910.
  Two common orchard mites, the brown mite and the red spider. B. 152, 1910.
  See Gillette, C. P. jt. author. B. 169, 1910.

- Western cricket. Life history and remedies. C. P. Gillette. Migratory habits. S. Arthur Johnson. B. 101, 1905.
- Western slope fruit investigations 1906. Report of field horticulturist. O. B. Whipple. B. 118, 1907.
- Western slope fruit investigations 1906. Report of the field entomologist. E. P. Taylor. B. 119, 1907.
- Western slope fruit investigation. Condensed report of the field entomologist 1906. E. P. Taylor. P. B. 42, 1907.
- Western slope fruit investigation. Report of the field horticulturist. O. B. Whipple. P. B. 43, 1907.
- Western slope fruit investigations. *See also* Horticulturist, field.
- Wheat—
  - analysis. B. 219 :19, 1916 (tables) ; B. 219 :55, 1916.
    - methods. B. 219 :124, 1916.
  - ash analysis. B. 217:38, 1916.
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  - characteristics of Colorado. B. 219 :18, 1916.
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    - compared to South Dakota. B. 219 :89, 1916.
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    - study of. B. 208 :3, 1915 ; B. 217:3, 1916 ; B. 219 :3, 1916 ; B. 237 :3, 1918 ; B. 244 :3, 1918 ; B. 247 :3, 1918.
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  - experiments at Boise, Idaho. B. 219 :104, 1916.
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  - flinty. B. 219 :38, 1916.
    - analysis. B. 219 :42, 1916.
  - flour—
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    - composition. B. 244:11, 1918.
    - milling results. B. 244 :11, 1918.
  - fungous diseases of. B. 212 :22, 1915.

- Wheat (Continued)—
  - grass, analysis. B. 12 :64, 1890.
  - hard, produced by nitrogen. B. 237 :12, 1918.
  - hybrid crosses, Mendelian characteristics of. B. 249:5, 1918.
  - irrigated and dry land. B. 244:25, 1918.
  - irrigation's effect on. B. 219 :45, 1916.
  - macaroni, culture experiments. P. B. 17, 1903.
  - milling types. P. B. in B. 123 :20, 1907.
  - mineral constituents of. B. 219 :25, 1916 (tables.)
  - nitrates effect on. B. 219 :67, 1916.
  - nitric nitrogen effect on. B. 219 : 116, 1916.
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  - notes. B. 26 :28, 1894 ; B. 30 :3. 1894.
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  - study of. B. 217, 1916 ; B. 219, 1916.
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  - water's effect on. B. 237:7, 1918.
  - water measurement applied to. B. 22 :13. 1893.
  - weather effect on. B. 244 :8, 1918.
  - weights of stems, leaves, and heads (tables.) B. 217 :24, 1916.
  - yellow berry in. B. 205 :3, 1915 ; B. 219 :30, 1916.
    - experiments. B. 205 :23, 1915.
- Wheat raising on the plains. J. E. Payne. B. 89, 1904.
- WHIPPLE, O. B.
  - Dewberry growing. B. 136, 1909.
  - Grape growing. B. 141, 1909.
  - Peach mildew. B. 107, 1906.
  - Pruning mature fruit trees. B. 139, 1909.

WHIPPLE (Continued)—
  Top-working fruit trees. B. 147, 1909.
  Western slope fruit investigations 1906. Report of the field horticulturist. B. 118, 1907.
  Western slope fruit inevstigations. Report of the field horticulturist. P. B. 43, 1907.
  Western slope fruit investigations. R. 19-21, 1906-1908.

White—
  arsenic. See Arsenic, white.
  hellebore. See Hellebore, white.

Whorled milkweed. See Milkweed, whorled.

Wild—
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  cherry, notes. B. 211:36, 1915.
  pea. See Lupines.
  rye. See *Elymus canadensis*

WILLIAMS, JOHN O.
  Horse Breeding Experiment Station. Report of. R. 22-26, 1909-1913.
  Information concerning the Colorado Carriage Horse Breeding Station. B. 166, 1910.

Windbreaks and shelter belts for the plains. B. O. Longyear. P. B. 35, 1907. Same. B. 123 :15, 1907.

Windmill irrigation. Hints to plains settlers. J. E. Payne. P. B. 53, 1910.

Windsor reservoir, water analysis. B. 82 :24, 1903.

Winesap apples, thinning. B. 170, 1910.

Winter and frost injuries of fruit trees. Thinning of the winesap. R. S. Herrick. B. 170, 1910.

Winterhalter, Mr. fertilizer experiments, 1904. B. 183 :14, 1912.

Wire grass *(Juncus balticus.)* B. 12 : 125, 1890.
  (Poa compressa.) B. 12 :13, 1890.
  (Aristida longiseta.) B. 211:19, 1915.

Woodbury blight cure—
  ineffectiveness of. P. B. 6, 1900; Same. B. 64 :17, 1901.

Woods, W. Market development of the Rocky Ford cantaloupe. B. 108 :14, 1906.

Woody aster *(Xylorhiza parryi)*—
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Wooly aphis. See Aphis, wooly.

Wooly plant louse. See Aphis, Wooly.

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Xanthium echinatum. See Cocklebur.

Xylan in alfalfa hay. B. 39 :18, 1897.

Xylorhiza parryi. See Woody aster.

Yellow berry in wheat, its cause and prevention. W. P. Headden. B. 205, 1915.

Yuma, Colorado—
  precipitation 1891-1911, B. 182:54, 1912; 1891-1917, B. 245 :59, 1918.

Yuma County, agriculture. B. 59 :12, 1900.

Zinc arsenic. B. 210 :44, 1915.

Zophodia bella. See Currant fruit worm; Gooseberry fruit worm.

Zygadenus venenosus See Death camas.

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Bulletin 264 October, 1920

The Agricultural Experiment Station

OF THE

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PERENNIAL PEPPERGRASS

A NOXIOUS WEED IN COLORADO

BY

A. K. PEITERSEN and R. T. BURDICK

JUN 29 1945

1879

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
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PERENNIAL PEPPERGRASS
A Noxious Weed in Colorado

By A. K. Peitersen *and* R. T. Burdick

I. Introduction—Recently the perennial peppergrass has become of such frequent occurrence in Colorado that unless prompt action be taken for its control it is almost certain to spread itself over most of the cultivated areas of the state. During the past season this station has received numerous urgent appeals for some definite advice concerning methods for controlling this pest. These appeals have come from widely different sections within the state. It was therefore thought that a preliminary report on this noxious weed might be timely in acquainting the farmers of the state with the characters of this introduced plant and in this way its introduction into uninfested areas might be prevented. Preventing its introduction into new fields is far easier than prescribing methods for its eradication when once established.

II. Name and Description—The perennial peppergrass is botanically known as Lepidium draba L. but in common with other plants which are of economical importance or which have attracted the attention of the passer-by it is recognized by a number of common names such as: Perennial Peppergrass, Hoary Cress, Turkestan Mustard, White Weed, and a number of other local names which are generally descriptive of the plant. In the San Luis Valley it is commonly referred to as the Perennial Peppergrass, while in the Grand Valley it is more frequently called White Weed. The former name, however, is used most generally throughout the United States.

This plant is an erect perennial, ten to twenty inches high, having a much-branched inflorescence, spreading profusely by underground root stocks. Its leaves are oblong or lanceolate, obtuse and slightly toothed, 1½ to 3 inches long, whitish-pubescent, the upper sessile and clasping the stems, the lower long and petioled. Inflorescence consisting of white, showy flowers; pedicels long; the 2-carpellate pistil ripening into a flattened fruit having a slender style about ⅛ inch long; pods somewhat heart-shaped and wingless, usually containing one mature seed; seeds dark brown, somewhat tapering at one end and about the size of alfalfa seed. (See Plate I.)

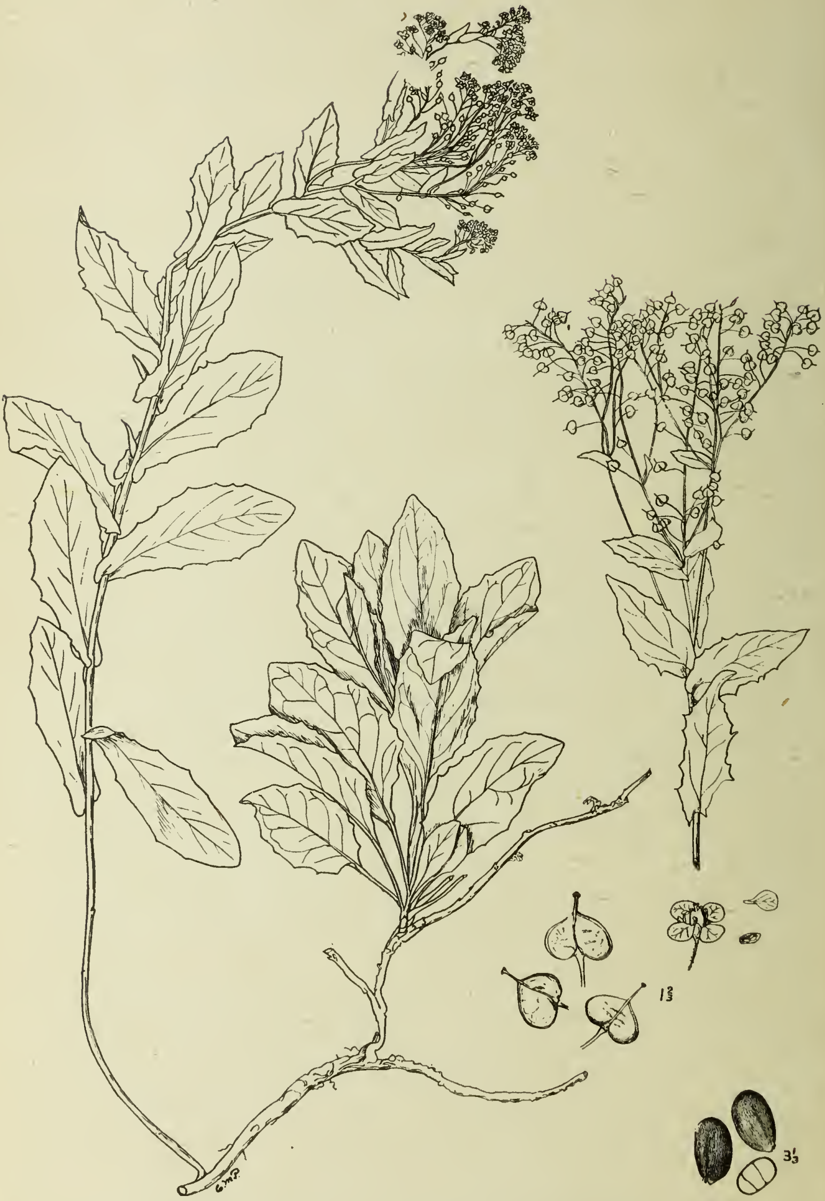

Plate I—Perennial Peppergrass (Lepidium draba L.) two-fifths natural size.

III. Other Related Plants—The Perennial Peppergrass is a member of the mustard family and is a very close relative of the common field peppergrass (Lepidium apetalum L.) It is often confused with the less common species of this genus; especially Lepidium jonesii Rydb. and Lepidium scopulorum Jones which are also quite abundant upon the Western Slope and in the San Luis district. These resemble it somewhat in general appearance; especially in their showy inflorescence. However, anyone who has had field experience with this plant has no difficulty in distinguishing it from either of these. Its characteristic spreading growth due to underground root stocks, its broad, whitish-pubescent leaves, the upper ones clasping the stem, its wingless pod bearing, a long slender style, and its large brown seeds are distinguishing characters of this plant.

IV. Its Introduction and Distribution—Lepidium draba L. is a native of central Europe and western Asia but is now quite common throughout continental Europe and the British Isles. Its first appearance in this country was noted about the seaports of New York, Washington and elsewhere which would seem to indicate that it has been carried into the United States on ballast or ship refuse. However, its almost simultaneous appearance in Colorado, Wyoming, and New Mexico suggests that it has also been carried into this country in foreign grown seed; possibly alfalfa seed.

At present its distribution in the United States is quite general in local and restricted areas. It has been reported from most of the eastern coastal states and a few of the central states such as: Michigan, Wisconsin and Iowa. On the western coast, especially in California, it is becoming a serious pest. However, in no localities in the United States does it seem to be as pernicious as in the Rocky Mountain region at altitudes from 4,000 to 8,000 feet. In Wyoming, Idaho, Colorado and New Mexico it is already a serious pest in many districts.

It made its appearance in Colorado some twenty years ago. Its presence in this state was first noted by C. S. Crandall who collected specimens of this plant in 1898, growing in the vicinity of Palisade. From there it has spread until now it is established in local areas in most of the irrigated land of the state. Plate II shows its present distribution in Colorado. The shaded portions of this map indicate the parts of the state where this plant is found growing, but only in very restricted areas and sometimes only a few plants at a station. It is especially troublesome in the Grand Valley and the San

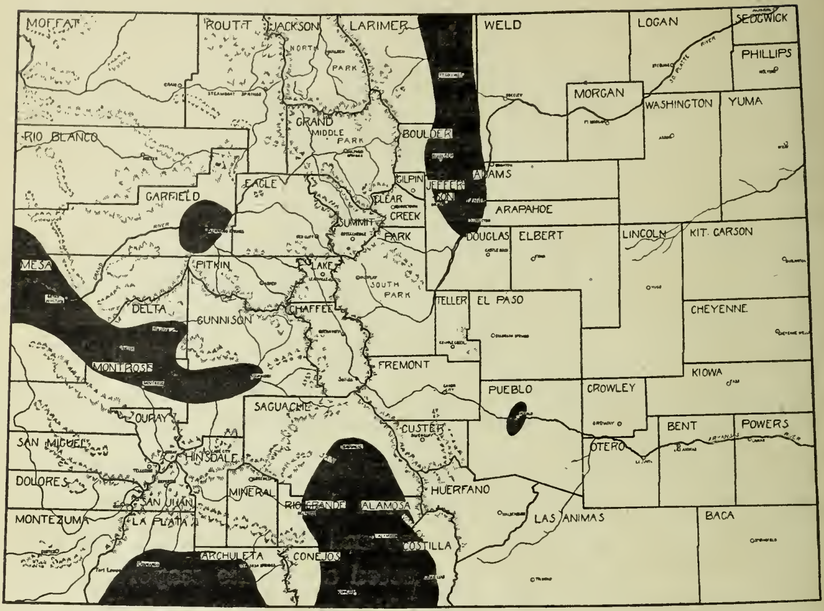
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Plate II—Map showing distribution of Perennial Peppergrass in Colorado. Shaded areas indicate localities from which it has been reported.

Luis Valley where in many instances entire alfalfa fields have been invaded.

V. Methods of Dissemination—Considering the habits of this plant it is almost certain that in time it will spread over most of the state unless effective control measures are used. Its large, white, perennial, underground root stock, which in some instances penetrates the soil several feet and spreads horizontally in all directions, enables it to spread out from year to year. The writers have seen patches in alfalfa fields which have been invaded by this weed where the alfalfa plants have been completely crowded out and a hundred per cent stand of this pernicious pest has taken its place. Not only does it spread over fields in this way where it has gained a foothold but it is quite frequently introduced into new localities by the dissemination of its seeds in foul alfalfa. The size of the seed is quite similar to that of alfalfa and unless purity tests have been made of such seed it is very apt to escape the attention of the purchaser. The Colorado Seed Laboratory received, during the past year, nine lots of alfalfa and sweet clover seeds which contained this impurity. Eight of these samples were native grown.

VI. Methods of Eradication and Control—Perennial Peppergrass belongs to a class of plants which is most difficult to eradicate from the soil. As has already been noted the plant has well developed root stocks which are able to penetrate the soil for several feet in a horizontal direction from the original plant. During the season's growth these root stocks store up food which is used during the next year to send out new shoots from the joints of the root stocks and these new shoots develop into new plants. Before the plant can be killed the root stocks must be removed from the soil or killed in some other manner. This is a difficult proposition. Starvation of the root stocks by allowing them to send out new shoots which are cut off as fast as they develop will finally kill them. This is much easier said than done as the food stored up in the root stock is sufficient to send up a dozen or more shoots before it is exhausted. A farmer will successfully cut off the first two or three shoots but by the end of that time his faith in the method of control will weaken and he will neglect further cultivation. The next shoot will grow and store up new food in the root stock. As a result of his omission to kill the third or fourth plant the weed will return to its first vigorous condition.

A method of control of this weed to be effective must be one that is easily applied, that fits in with regular farm work and is not too expensive. It is difficult to find any one method that meets these conditions. Prevention is far more effective than cure in this case but unfortunately many farmers are not in a position where they can successfully prevent the weed from becoming a pest on their farms. At the present time it is being distributed with alfalfa or sweet clover seed. Farmers should refuse to buy and sow any alfalfa or sweet clover seed when the analysis of the State Seed Laboratory indicates the presence of perennial peppergrass seed. Once the weed is established it will require the most persistent efforts of farmers who are awake to the seriousness of this pest to completely eradicate it as one individual plant which escapes them is able to re-seed the field.

Following are some methods which have been tried in controlling this weed:

First—Eradication by clean cultivation. This means what has been outlined above, namely keeping the ground absolutely free from any of the plants. To do this it will be necessary to thoroughly disc or cultivate the field at least once a week and sometimes twice in the growing season so that at no time will the plant have a chance to keep a leaf growth above the ground. One year of thorough treatment of this type should so weaken the plant that the second year a cultivated crop such as potatoes, sunflowers, or corn could be grown and given thorough clean cultivation, with special care that no perennial peppergrass plants are allowed to grow. The objections to this method are that it sacrifices one year's use of the land and that it requires constant attention and thorough cultivation regardless of other farm work. This practically means that the method will never be successfully used except in individual cases. It is, however, when used, a most reliable method.

Second—A method which has been suggested is to plow the field, fence it, and turn in some hogs with noses in working condition. If enough hogs are used they will dig up the patch and eat the majority of the root stalks. The pasture should be watched and, if

Plate III—An expensive but sure method of eradication.

necessary, either re-plowed or hand hoed. This method will prove effective and eliminate perennial peppergrass in small areas.

Third—Another method is to fence off the patch and turn in sheep, which eat it very readily. They will crop the weed close to the ground and eventually exhaust its vitality. This is not as effective as the hogs and is of doubtful value but it will prevent the weeds from forming seeds and in that way check somewhat the spread.

Fourth—The weed, when in small patches, can be killed by completely covering the ground with some material that shuts out the light and prevents the plant from growing through it. Plate III shows this method as used by Mr. Luther Norland of Sanford.

Mr. Norland put roofing over the infested spots and extended it out two feet beyond the weed in all directions. He found it necessary to lap the roofing and nail it to 1x2 inch strips of lumber in order to prevent the weeds from forcing their way between the strips of roofing. This method will require that the patch be fenced off so that livestock will not walk over the roofing and make holes through it, and it is recommended that the field be left covered for two years. Care should be exercised in extending the roofing at least two feet in all directions beyond any visible signs of the plant as it is able to force its way a considerable distance horizontally. This method is expensive in first cost but if properly protected the same roofing can be used later in another place. This is probably the most effective cover that we have seen in use. Almost any other material which can be used would not prevent the shoots from coming up to the surface through some crack or crevice.

In addition to the above methods chemical sprays have been used effectively in combating many of our worst weeds. Plants of the mustard family are especially susceptible to chemical treatments. Although no spraying experiments have as yet been carried out with this species, it is known that an iron sulphate spray will kill the common peppergrass. The objection to this, however, lies in the fact that the spray kills only that part of the plant above the ground. Consequently one spraying is no more effective than one cultivation and to make it effective it would be necessary to spray the patch several times during the season.

If salt is used as a control measure a sufficient quantity must be spread over the soil to make it strongly akaline. This will not only kill the peppergrass but will also destroy all other vegetation. If this is done, however, the salt can be removed from the soil by flooding and proper drainage during a few seasons.

All the above suggested methods of eradication apply to the plants already established in the soil. Generally peppergrass seed in the soil will not retain its vitality for more than two seasons. Seed, therefor, which is already in the soil, would be destroyed by the above treatments, especially clean cultivation, smothering, or the salt treatment.

As has been noted previously, it is far easier to prevent its introduction than to eradicate the plant when once established, and it is the purpose of this report to impress upon farmers the necessity of combating this weed before it becomes a serious and widely disseminated pest.

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Bulletin 265 February, 1921

The Agricultural Experiment Station

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The Venturi Flume

By Ralph L. Parshall, Senior Irrigation Engineer
Carl Rowher, Irrigation Engineer
Irrigation Division, Bureau of Public Roads
U. S. Department of Agriculture

1945

This bulletin is based on experiments conducted in the hydraulic laboratory at Fort Collins, Colo., at Cornell University, and at the field laboratory at Bellvue, Colo., under co-operative agreement between the Irrigation Division of the Bureau of Public Roads, U. S. Department of Agriculture, and the Colorado Agricultural Experiment Station.

1879

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLO.
1921

The Colorado Agricultural College

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THE VENTURI FLUME

By

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A preliminary report on the Venturi flume was prepared by V. M. Cone and published in the Journal of Agricultural Research, Vol. IX, No. 4, April 23, 1917. This report was not intended to cover the whole subject, but rather to present the possibilities of this device as a practical means of measuring flowing water for irrigation purposes. The original investigations were made at the hydraulic laboratory at Fort Collins, Colorado, but, due to the inadequate facilities, it was not possible to carry the experiments to the point most desirable from an irrigation standpoint. Under a co-operative agreement between this Bureau and Cornell University, experiments were conducted at the Cornell hydraulic laboratory under the supervision of Dr. Schoder and the late Professor Turner on the larger sized flumes, where flows of 300 to 400 second feet were used. Additional experiments were performed at the field laboratory on the Cache la Poudre river at Bellvue, near Fort Collins, Colorado, in order to properly correlate all the tests previously made. All these data were not available at the time of the first published report, and in our subsequent study, various characteristics of the flume have become apparent which were not evident when the original experiments were made.

This bulletin is intended to present a more complete statement as to the law of flow through the Venturi flume and also to define more clearly its limitations and advantages.

Many devices have been developed for the measurement of water for irrigation, but, due to the great variation of the conditions as found in practice, no individual type has yet been found which exactly meets all of the requirements. The standard methods of measuring flowing water are all more or less affected by the ever-changing condition of the channel, either immdiately above or below the structure, or else the capacity of the device limits the discharge.

The overpour, sharp-crested weir is the most accurate method of determining the quantity of flow, but certain requirements as to contractions and velocity of approach must be maintained in order to keep the weir standard. The accuracy of measurement is only possible at the expense of considerable loss in head or grade of the channel, and in many cases the installation of the standard weir is impossible on account of the lack of fall. This is especially true where large quantities are to be measured. Where the water carries considerable silt, there is a tendency to fill the weir basin with sediment, which affects both the contractions and the velocity of approach. The submerged orifice and weir are limited to practically the same requirements, in so far as contractions and velocity of approach are concerned, but permit of operation under conditions where a small loss of head is important.

The rating flume, which is nothing more than a constant section through which the water passes, is the accepted standard for the measurement of the comparatively large flows. This method of measurement is subject to various effects, and is only rarely found to maintain a constant condition. Experience indicates that, in the majority of cases, the rating flume is wholly unreliable, due to the change of velocity of approach, silting conditions in the flume and the accumulation of vegetation in the channel, as well as along its banks. It is not uncommon to find the rating flume affected by check boards, placed in the channel below the flume, for the purpose of raising the water sufficiently to permit the irrigation of higher lands.

The Venturi flume has been developed to meet these various conditions; however, it is not claimed that this device is accurate to the last degree, but under ordinary conditions it is believed to be very much more dependable than our present accepted methods. A number of these Venturi flumes have been installed and are in actual use, and it has been found that this new device possesses the following desirable features: *

1—It is moderately inexpensive and simple to construct.
2—It is simple in its operation.
3—It requires little maintenance.
4—It is free from working parts.
5—It is sufficiently accurate to meet practical needs.
6—It is unaffected by sand, silt or floating trash.
7—It requires but little loss of head in its operation.
8—It possesses a very wide range in its capacity of discharge.

Altho the Venturi flume possesses many very desirable features, there still remain certain defects in the present design that work to its disadvantage. It is believed, however, with further

*(Journal of Agricultural Research, Vol. IX, No. 4, V. M. Cone)

experimentation, that some of the undesirable features can be very greatly modified, if not entirely eliminated. In order to completely correct these defects, it may be necessary to change the design of the present flume in some respects in order that a more uniform or stabilized condition will exist in the down stream or diverging section. In view of the fact that considerable work had already been done on the present type of flume, and further, since a number of these flumes are now in operation, it was thought advisable to complete the investigation along the original lines, and later to continue with the idea of attempting the improvement of the present flume.

The present type of Venturi flume (Plate 1) consists of a contracted section through which the water passes, or essentially, a flume with a converging and diverging section, with a short "throat" section between them. The effect of passing liquids through converging and diverging tubes was known to the Romans, and later, in 1797, Prof. Giovanni Battista Venturi, an Italian philosopher, studied this phenomenon and after many careful experiments performed at the University of Modena, stated the law in definite form. Nearly 100 years later, Clemens Herschel made the practical application of the Venturi principle to the measurement of water flowing through pipes. The Venturi flume is an adaptation of the

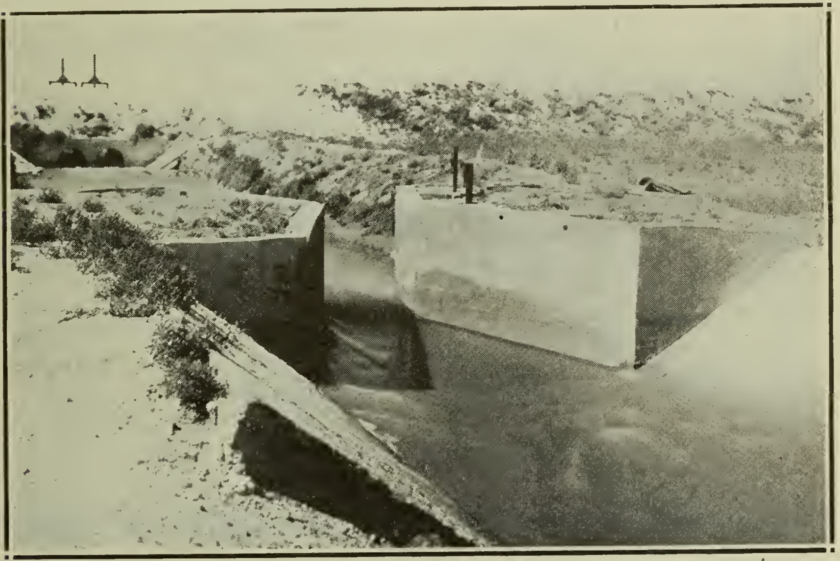

PLATE I.—Field Installation of Three Foot Concrete Venturi Flume of Rectangular Cross Section.

Venturi principle, but the water passes the contracted section without pressure; that is, exposed to atmospheric pressure only. The Venturi principle, as applied to an open flume, manifests the same characteristics as when the flow is confined in a tube; namely, there is a reduction in the head at the contracted section.

The floor of the Venturi flume is level and placed at the elevation of the grade of the channel. The short throat section forming the contraction has been arbitrarily taken as 1 foot long for the various sizes calibrated, and midway along the axis of the throat the head is observed. The head in the converging section is observed at a point on the side of the flume. This point is twice the width of the throat from the upper edge of the throat, and this distance is measured along the longitudinal axis of the flume. This distance was arbitrarily taken so as to give a point well within the converging section, and to be so situated as to correctly register the head at that point. The flow through the flume will be a certain function of these two heads, and the width of the throat.

In the preliminary investigation of the Venturi flume, various slopes of the converging and diverging sections were tried out, and from the standpoint of economy and the general behavior, it was decided to base all the calibrations of the various sizes of rectangular flumes on the general plan that the total length of the flume would be six times the width of the throat, plus 1 foot, and that the width of the flume at either end would be three times the width of the throat, but more recent observations prompted the suggestion that this originally assumed plan should be somewhat modified.

Our investigation so far has been confined very largely to the rectangular flumes; that is, those where the throat section is defined by two vertical faces, each 1 foot in length, measured along the axis of the flume and placed parallel to and equidistant from this axis. The V-notch and trapezoidal flumes; that is, those where the throat sections are defined by two sloping faces, have been tested, but the inadequate facilities for making the tests prevented calibrating the flumes of this type for large discharges.

Field calibrations of trapezoidal flumes have been attempted but with little success. As a usual thing, the field installation provides little or no regulation for the purpose of extending the observations over any considerable range. It is hoped that more complete information may be obtained on a series of trapezoidal sections which would permit of establishing the law of flow through this type of structure. At present the only data available for the trapezoidal flume are found in the Journal of Agricultural Research, Vol. IX, No. 4, Apr. 23, 1917.

The Venturi flume is very simple in operation, altho two heads must be observed to determine the rate of discharge. It is recommended that the observations of head or depth be made in still boxes or gage wells, so placed that the water level in the throat, and also the point indicated in the converging section can be communicated to these boxes or wells by means of short lengths of pipe. The observations of head or depth can best be determined by means of a hook gage located in each well. However, a plumb bob or a weight of special design, to be referred to later, suspended on a graduated tape may be used in lieu of the hook gage. Investigations, as well as observations under practical conditions, seem to indicate that heads determined by means of graduated scales fastened to the inside surface of the flume, countersunk until flush

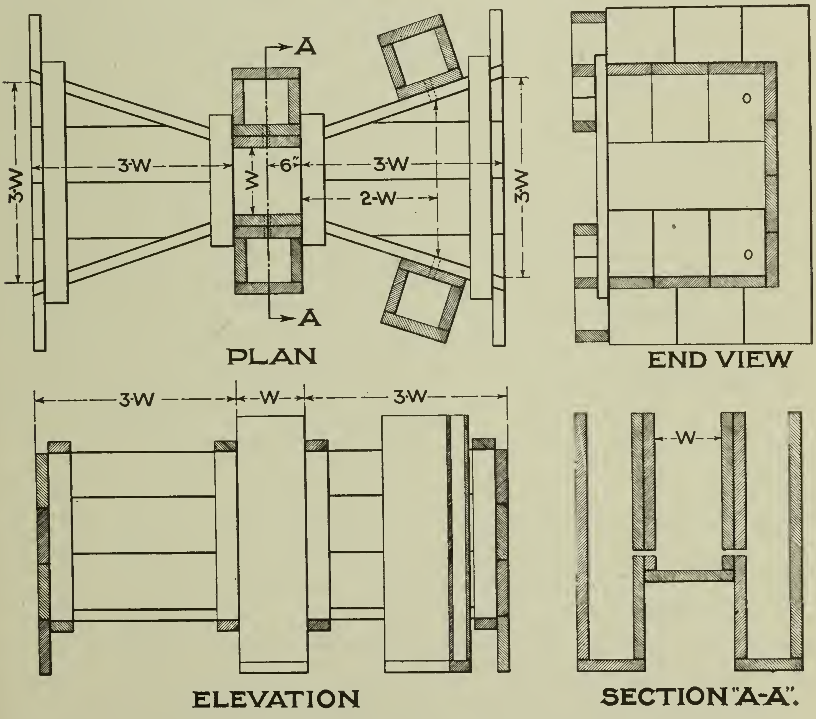

FIGURE 1.—Standard Plan for Venturi Flume with Rectangular Cross Section.

with the surface, do not give the best results. It was first thought that two points of observing the heads would be sufficient to definitely establish the conditions of flow for rectangular flumes, but due to the switching of the current in the diverging section, it was found necessary to observe the head at identical points on each side of the flume. The introduction of additional points of observing the head is not a desirable feature, but is necessary to insure the dependability and accuracy of the device. Table 1 gives the errors introduced into the discharge by determining the heads from one set of gage wells which register the depths on one side of the flume only. To avoid the possibility of uncertainty in the readings and to obtain a more correct determination, it is suggested that the arrangement of wells and connections be made as shown in Figure 1.

It has been suggested that a narrower diverging section might so modify the downstream conditions as to permit of reliable results from reading one side only; however, this restriction would no doubt greatly increase the mean velocity at the exit of the flume, thus causing a scouring action in the channel immediately below the structure which would require the installation of protection against this action.

The velocity of approach to the Venturi flume has no effect upon the accuracy of this device. When a certain quantity is flowing through the flume, drawing its supply from a still water basin, there will be a definite head at the gage connection in the converging section and in the throat, also a definite difference in head. If this same discharge were to approach the flume with a velocity, the upper gage reading would be less as would also the throat reading, and the difference in head would be greater. Since the upper head is less, the difference must be greater to permit of the same discharge, and because of the increased velocity, the head at the throat section is automatically decreased to balance the change in the velocity of approach.

In the Venturi flume the loss of head, due to the structure, is small except when the difference in head is great. Under normal conditions met with in practice, the velocity head is recovered when the water leaves the lower edge of the flume. However, when the difference in head is large, the water will maintain its high velocity through the flume and will not become normal until some obstruction, as an irregularity in the downstream channel, causes the formation of standing waves and the change from a high to a low velocity.

The fact that obstructions might occur in the flume is of considerable importance, and actual tests have been made to ascertain the effect of placing such obstructions in the flume in both the converging and diverging sections. The preliminary investigations made in 1915 on the V-notch flume brought out the fact that placing a 2-by 4-inch timber on edge, nailed to the floor of the flume at a point 3 feet above the throat section, did not increase the discharge by more than one per cent for any depth. Similar tests on a V-notch flume installed at the field laboratory at Bellvue, Colorado, showed the same result. In addition, it was found that placing the 2-by 4-inch timber on the downstream end of the flume had no appreciable effect.

Recent tests on a 3-foot rectangular flume show that 2-by 4-inch timbers nailed vertically to the sides of the converging sections, above the upper gage connections with 2-inch projection, had no effect; also the 2-by 4-inch timber on edge on the floor of the flume at a distance one foot above this gage connection had no effect, but when the timber was placed one foot below, or downstream from the connection, the effect was to increase the upper head so as to indicate approximately 4 per cent increase in the discharge when flowing 10½ second feet. Small strips placed transversely on the floor, projecting one-half inch, both in the converging and diverging sections, had no effect on the discharge. The deposit of sand and silt upon the floor of the flume has been found to be of small consequence, due to the fact that, as the converging section decreases in area, the velocity increases and the tendency for settlement or deposit is eliminated. Large floating masses would no doubt lodge in the throat section if the rectangular flume were installed, but this trouble could be effectively met by the installation of the trapezoidal section which would pass the lodging mass by the increased or accumulated head above the structure.

Requests have been made for information and data relative to Venturi flumes having capacities for more than one thousand second feet, but facilities and equipment are not available at present for undertaking the calibration of flumes of more than 30 second feet capacity. The law of flow, as has been determined from our experimental data, is applicable to sizes up to and including the five foot throat, but only approximations can be made for larger sized flumes by the application of the known law of flow. It is thought that the present range of calibration of flumes will meet the ordinary demand, and special cases requiring exceptional capacity will necessitate individual rating or calibration.

The Venturi flume is gaining in favor as a practical device, and the fact that it possesses many desirable features and few objectionable points bids fair to establish it as one of the standard measuring devices for practical irrigation purposes. The present design is not free from all objection, and is not claimed to be absolute in its operation, but when compared with other means of measurement it is found to be within reasonable limits of accuracy.

RECTANGULAR VENTURI FLUME

Since the publication of the first report on the Venturi flume, there has been a great number of these flumes built and installed for use in the measurement of water to irrigators. So far the greater per cent has been the rectangular type, and it appears to be somewhat more popular than the trapezoidal flume; however, there has been a number of the trapezoidal Venturi flumes installed, the calibration having been made by the interested parties.

The preliminary investigations of the Venturi flume resulted in a selection of certain ratios and dimensions applicable to a standard plan for the rectangular type. The assumptions as to dimensions were based on conclusions made evident by the behavior of model flumes of various ratios, and for uniformity the length of throat for all the sizes tested has been made one foot. The angle of convergence and divergence is equal and constant for the various sized flumes calibrated. The dimensions for the rectangular Venturi flume are shown in Figure 1. The calibration of this flume has covered a great many individual tests and includes the 1-, 1½-, 2-, 3-, and 5-foot sizes. The measured discharge has ranged from less than 1 to nearly 400 second feet in the calibration of this type of flume.

The diagrams and tables pertaining to the rectangular flume contained in this bulletin are based on the data collected at Cornell, our original data, and the more recent calibrations made at our field laboratory at Bellvue, Colorado.

As previously stated, our recent investigations indicate the desirability of providing the flume with four gage wells, two on each side of the flume. Tests were made to determine the per cent of error resulting from taking the readings in only one set of gage wells. Table 1 gives the results of these tests. In this table, the deviation from the true amount is either plus or minus, depending upon which side of the flume the observation wells are located; or in other words, which side the current is flowing in the diverging section with reference to the gage wells. If the current is flowing in the diverging section on the side of the observation wells, then the amount recorded will be more than the actual discharge; if the observations are taken on the opposite side from the current in the diverging section, then the reverse is true. Mean readings of simultaneous observations taken in four wells, as shown in Figure 1, will, under ordinary conditions, give the true gage height.

The derivation of the expression for computing the discharge through rectangular Venturi flumes is somewhat involved, and no attempt will be made to go into detail. As a general statement, it may be said that the basis of deduction is Bernoulli's theorem, which results in the following for the theoretic discharge:

$$Q=C\ W\ H_b \sqrt{\frac{2g\ H_d}{1-\frac{9}{49}\left(\frac{H_b}{H_a}\right)^2}}$$

Where Q=discharge in second feet,
W=width of throat in feet,
H_b =head at the throat in feet,
H_a =Head in converging section in feet,
$H_d=(H_a-H_b)$=difference in the two heads,
C=constant.

The value C, is really not a constant but varies with the width of the throat and also with the upper head, H_a, and the difference in head H_d. This variation is expressed by the following formula:

$$C=(0.9975-0.0175W)+\frac{(H_d-0.163\ H_a{}^{1/2})^2}{\left(\frac{8}{20-W}\right)H_a^2}$$

which, when substituted for C in the theoretical equation, gives:

$$Q=\left[(0.9975-0.0175\ W)+\frac{(H_d-0.163\ H_a{}^{1/2})^2}{\left(\frac{8}{20-W}\right)H_a^2}\right] W H_b \sqrt{\frac{2g\ H_d}{1-\frac{9}{49}\left(\frac{H_b}{H_a}\right)^2}}$$

The discharge diagrams, Figures 13, 14, 15, 16, 17 and 18 appended to this report, are based upon calculated values as determined by this expression. These curves are plotted on a logarithmic scale which presents the data in such a form as to be readily understood and applied. The use of the diagram can best be illustrated by an example. Assume a 2-foot Venturi flume with an upper gage height of 1.26 feet and a difference in head of 0.21 feet. In Figure 15, find the difference in head, 0.21, in the column on the left of the diagram, midway between the two horizontal lines, follow across the diagram horizontally until the 1.20 upper gage height curve is reached; estimate the fractional part and then read the discharge of 8.0 cubic feet per second at the bottom of the diagram vertically beneath this point. In determining the discharge, care should be observed in noting the change in the scale dimension in the different parts of the diagram.

It will be observed that for each upper head there is a limiting point, beyond which the curve does not extend. This limit is represented in the diagram by the curve designated as "free flow." This results from the fundamental theory of flow through contractions in channels. For every upper head as the difference in head increases, a point is finally reached beyond which the difference in head can no longer be increased. This is the point at which the maximum discharge occurs. This condition has been observed experimentally and it was found that it occurred when the throat gage registered from 50 to 60 per cent of the upper gage. This percentage varies with the size of flume and the upper head, increasing as the size of the flume increases and decreasing as the upper head increases. After the free flow condition has been reached, the depth of water in the diverging section may continue to drop without affecting the discharge or the gage heights.

Some idea as to the accuracy of the rectangular Venturi flume may be gained by inspecting the diagram, Figure 2, which is based upon comparisons of actual discharge with the quantity determined by computation, the basis of the computed values being the empirical expression developed from the experimental data. It will be noted that the per cent of deviation of the observed discharge from the computed quantity is largely confined to errors of less than 5 per cent; however, it is apparent that an occasional point is considerably more in error. This diagram is based upon 453 individual observations covering the calibration of the 1-, 1½-, 2-, 3-, and 5-foot rectangular flumes. The distribution of observations is quite uniform over the various sizes of flumes, and the compilation of the data for the comparison was made without selection or elimination.

The number of tests and the variety of conditions under which they were performed, seems to warrant the conclusion that with proper precaution quite dependable results may be expected.

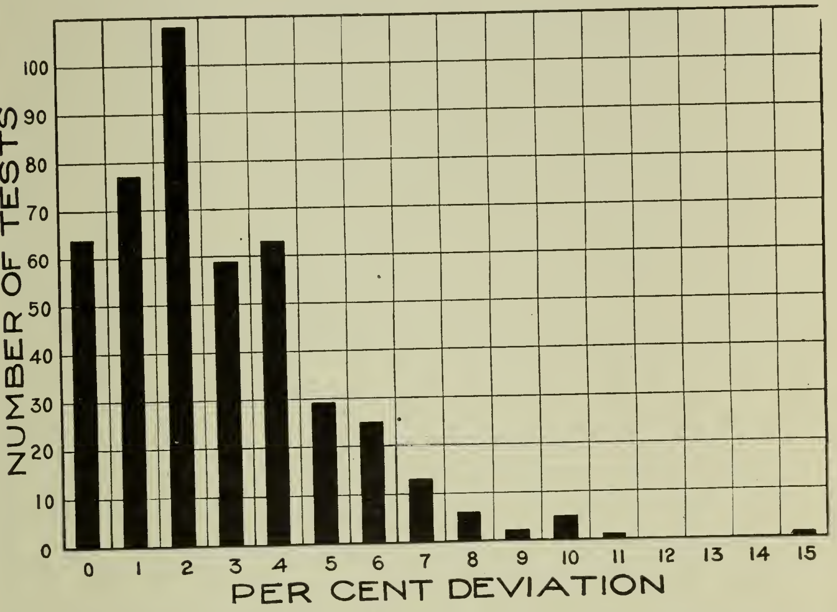

FIGURE 2.—Plot showing the Deviation of the Computed Data from the Experimental Data for all the Sizes of Rectangular Venturi Flumes Calibrated.

The installation of the rectangular Venturi flume should offer no difficulty as to construction or setting. Either concrete or wood may be used, but for the larger sizes and where permanency is required, concrete is recommended.

The flume should be located in the most desirable place with reference to alignment of ditch and grade. The floor elevation should agree with the grade line or bottom of the ditch in order that there will be no tendency to deposit silt or sand at the ends of the structure. If placed below grade, for small differences in head, the velocity within the flume is relatively low and would tend to silt the floor and cause trouble by stopping the pipe connections to the observation wells. It is recommended that the floor be a little above the grade rather than too low. The floor should be level in both directions and if constructed of concrete, should be given a smooth trowel finish. The most important element in the construction of these flumes is the dimension of the throat section. If concrete, it is recommended that the forms be set so that the distance between the two vertical faces will be from ¾ to 1 inch over size. After the forms have been removed, a finish coat of the required thickness should be put on to bring the width of throat to the correct dimension. The finished length of the throat measured along the axis of the flume is to be one foot, and if a plaster coat is added after forms are removed it will be necessary to make the cast face from 2 to 3 inches longer. This method of constructing the throat will insure a greater degree of accuracy in obtaining the true size. A trowel finish on the sides or walls of the flume is not absolutely necessary, but in most cases will add to the appearance and general utility of the structure. For wooden structures, see description of method given for V-notch flumes on page 23.

The observation wells should be cast in place and made a part of the structure. The tubes leading to these wells should be one-inch pipe, a single tube being sufficient, and should be placed two or three inches above the floor. These inlet tubes should be set flush with the inside surface of the flume, and it is important that they be normal or at right angles to this surface. The depth of the well should be sufficient to permit sand or silt to deposit and only require cleaning at long intervals. The well should extend somewhat above the general ground line, thus avoiding storm water washing trash into the well. Covers for the wells are recommended as a protection against foreign matter being deposited within them. At least one of the inside faces of the well should be made vertical and be provided with stud bolts for the purpose of anchoring a plank to support a hook gage or other measuring device.

Experience indicates that a graduated scale fastened to the inside face of the Venturi flume is not sufficiently accurate to determine the correct elevation of the water surface. The size of the wells would need to be comparatively large in cross section to permit of accurate reading of the scale if placed in the still wells. For the determination of the depth of water in the still wells above the floor of the flume, a depth scale, Figure 3, has been proposed which is simple in construction and operation, and when set will give the upper gage reading and the difference in head. The design of this scale is such as to eliminate the possibility of erroneous reading and also the chance of miscalculating the difference in the height of the two water surfaces. After the slides are once set, the readings may be read at leisure.

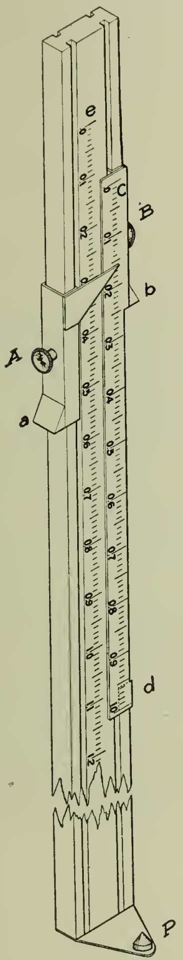

FIGURE 3 — Adjustable Scale for Determining the Upper Head and Difference in Head for Venturi Flumes.

At each gage well, fixed surfaces or supports are required which have the same elevation above the floor of the flume. It is thought advisable to have these surfaces protected by a metal plate to insure permanency. These supports should be provided with notches of sufficient length and depth to keep the rod vertical while observing the heads. To use this adjustable scale, set the slide (A) for the water surface in the upper gage well, and the slide (B) for the water surface in the throat gage well. It is immaterial which slide is first set. It is only necessary to move the whole rod vertically and at the same time to see that it is firmly held in the notch with one hand until the point (P) exactly coincides with the water surface. Securing this position, move the slide (A) or (B), as the case may be, downward until the stop (a) or (b) rests firmly against the plate mentioned above. The reading is similarly observed in the other gage well. The upper edge of the pointer on the slide (A) will indicate the head (H_a) on the scale (e) and the difference in head or (H_d) on the scale (c). These adjustable scales may be made of sufficient length to permit their use on moderately deep wells; however, care must be exercised in keeping the rod or scale vertical.

To locate the zero point of the scale (e) it is only necessary to measure vertically from the point (P) a distance equal to the difference in elevation between the floor and the top of the supports or notches on the wells. To locate the zero point of the scale (c), place the points (a) and (b) at the same elevation and adjust the scale to read zero as determined by the pointer on slide (A). Where one rod is to be used for a number of flumes, it will be necessary to have the fixed surfaces or supports on the wells at the same distances from the floor of the flume in all cases, or otherwise each flume will require a correction for the upper head reading.

Another practical way of determining the readings is by means of a tape and plumb bob, or special weight with a hook attached to the side, as shown at (a) Plate II. The steel tape should be reversed in direction; that is, the zero end attached to the case. A small sliding clamp is attached to the tape and when the point of the plumb bob, or hook of the special weight, just touches the water surface, this clamp is then moved downward against a stop, which should be located at a point above the floor of the flume equal to the distance between the point of the plumb bob or hook, and the zero of the tape. The reading indicated on the tape by the clamp will be the value of the upper head. To determine the difference in head, it is necessary to provide a fixed scale for the throat gage well, reading downward, with the zero at the same elevation as the stop for the upper gage well. By means of the tape, with the clamp reading the upper head, adjust the point of the plumb bob, or hook,

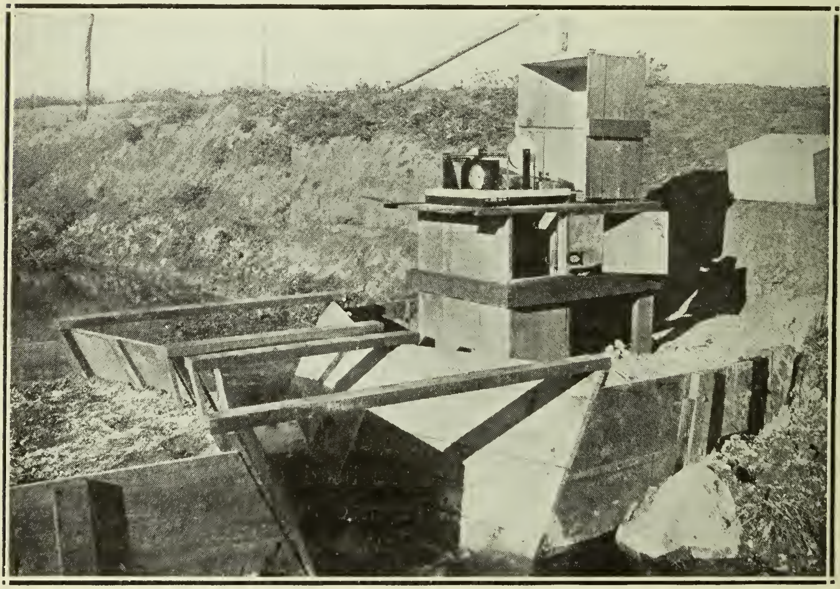

PLATE II.—Field Installation of V-Notch Venturi Flume and Automatic Gage Height Recorder.

to the water surface in the throat well. The index of the clamp will then give the difference in head as read on the fixed scale. This means of determining the readings is very advantageous as the tape and plumb bob can be carried about in one's pocket.

In order to have a continuous record of the depths of water passing through the flume, some type of recording instrument is required. The need of an instrument of this kind has been felt for some time, but not until recently has one been designed and built. This model instrument, built at the hydraulic laboratory at Fort Collins, is, in its general form, similar to the usual single stage recording instruments, but in addition to recording a single gage height, it also records the difference between two gage heights. An eight day chart is used where the depth scale is two inches to the foot, which permits the readings to be made to hundredths of a foot. The installation of such an instrument to record the gage heights is a simple and inexpensive operation. The gage wells should be large enough to accommodate a ten inch float, and the upper and throat gage wells should be placed side by side. The instrument should be mounted on a suitable support, in such a position as to permit the floats to freely actuate the recorder, and at such a height as to be convenient and easy to manipulate. A wooden box, hinged at one side and provided with hasp and lock, should be provided for field installation to protect the instrument.

Plate II shows the installation of this type of register in conjunction with the V-notch Venturi flume. If it is intended that a recording instrument be installed, special arrangement of the position of wells is necessary. The present design of the Venturi flume recording instrument requires that the two wells be in close proximity and separated by a thin partition wall, common to both wells. To successfully install this instrument will further require that some means of communicating the heads from the opposite side of the flume to the float wells be provided. A pipe of moderate dimension should be placed beneath the floor of the flume and connected to each pair of wells. As a practical means of testing the pipe connections, or tubes, it is suggested that the wells be filled with water by means of a bucket and the rate of drop in the water surface observed.

It is of considerable practical importance to know what conditions will obtain after the Venturi flume has been installed in the canal. The loss of head or difference in the elevation of the water surfaces above and below the structure, when the flume is in operation, has been observed for a considerable range of discharges for the various sizes of rectangular flumes. These data have been prepared in the form of diagrams as shown in Figures 4, 5, 6, 7, 8 and 9.

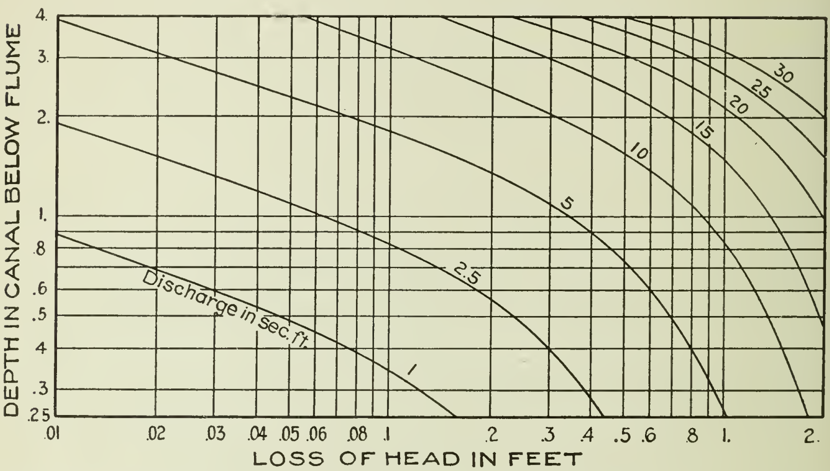

FIGURE 4.—Curves Showing the Loss of Head in Feet in a One Foot Rectangular Venturi Flume for Different Depths and Discharges.

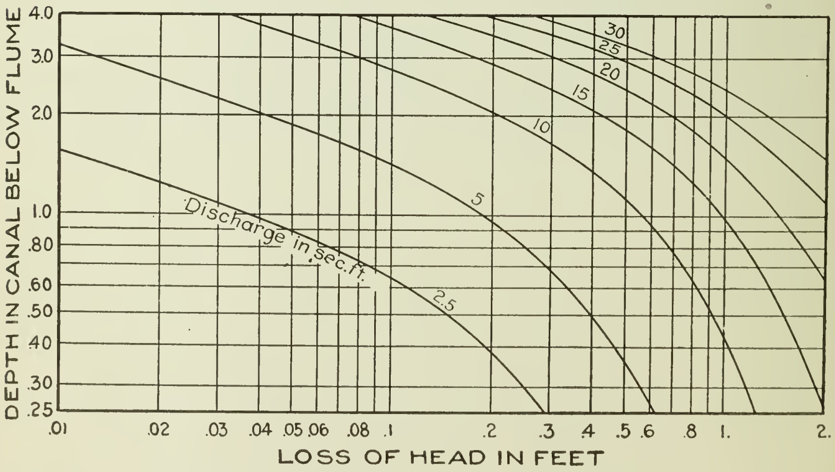

FIGURE 5.—Curves showing the Loss of Head in Feet in a One and One-Half Foot Rectangular Venturi Flume for Different Depths and Discharges.

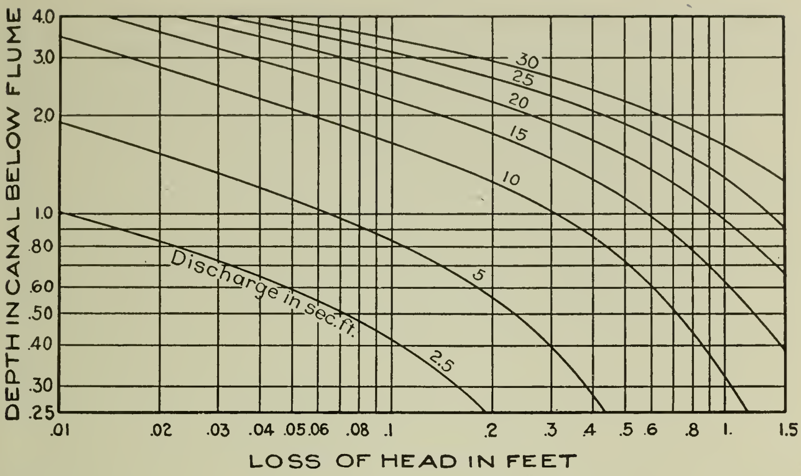

FIGURE 6.—Curves Showing the Loss of Head in Feet in a Two Foot Rectangular Venturi Flume for Different Depths and Discharges.

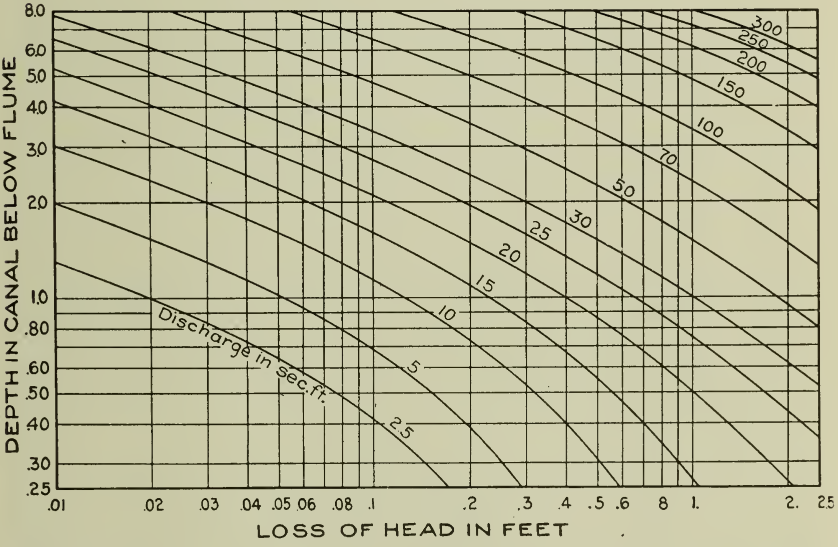

FIGURE 7.—Curves Showing the Loss of Head in Feet in a Three Foot. Rectangular Venturi Flume for Different Depths and Discharges.

The use of these diagrams is in approximating the increase in depth of water in the canal above the flume due to the obstruction caused by the throat section. As an example of the application, let it be assumed that the canal is 12 feet wide on the bottom with a normal carrying capacity of 50 second feet. Since the 4-foot Venturi flume has a width of 12 feet at the ends of the structure, it is evident that this size should be installed. As the condition exists before installing this flume, it is observed that the depth of water is approximately 2½ feet. Figure 8 shows the loss of head through this size flume, and for a depth of 2½ feet it is observed from this

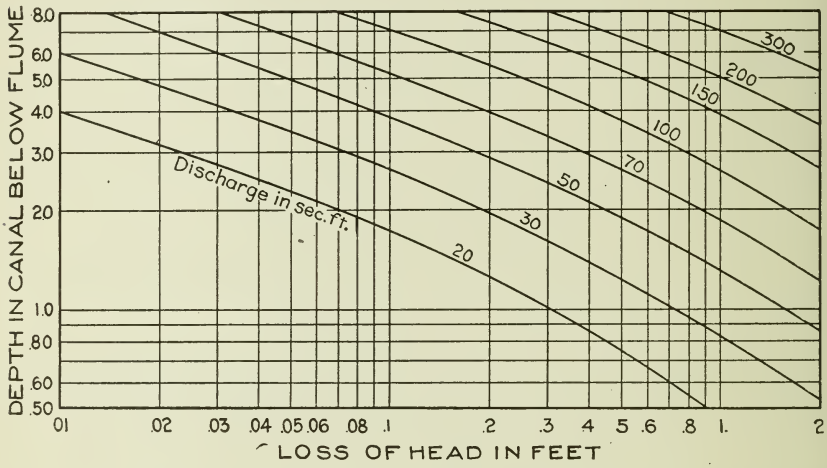

FIGURE 8.—Curves Showing the Loss of Head in Feet in a Four Foot Rectangular Venturi Flume for Different Depths and Discharges.

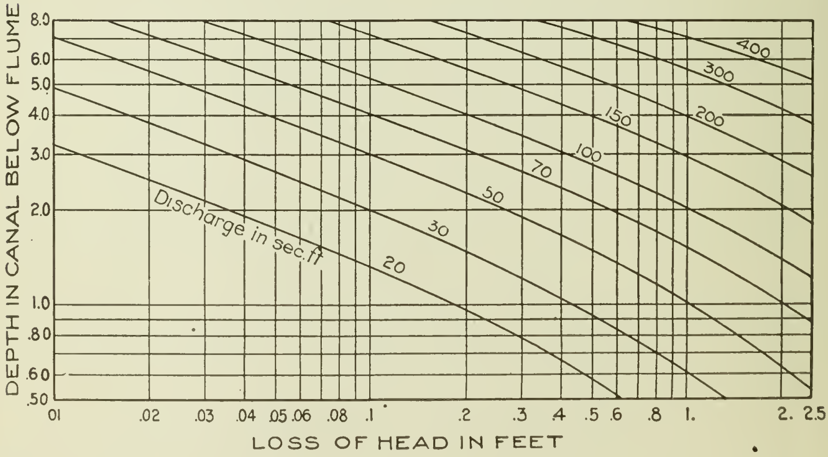

FIGURE 9.—Curves Showing the Loss of Head in Feet in a Five Foot Rectangular Venturi Flume for Different Depths and Discharges.

diagram that a loss of head of 0.3 feet would occur. This amount, added to the downstream depth, will be approximately 2.8 feet, or the depth above the flume when discharging 50 second feet.

V-NOTCH VENTURI FLUME

For a number of years there has been a demand for a measuring device that would accommodate comparatively small flows with a minimum loss of head through the structure. To meet this need, a V-notch Venturi flume has been calibrated for flows from 0.1 to 10 second feet. In this flume, the throat is formed by two plane surfaces, one foot wide and intersecting at the floor line at an angle of approximately 53°, or with a side slope of ½ to 1. The sides of the converging and diverging sections also have this same side slope, measured in the plane normal to the axis of the flume. Plate II shows a V-notch flume and automatic gage height recorder, installed in a small stream. The standard dimensions of this special type flume are given in Figure 10.

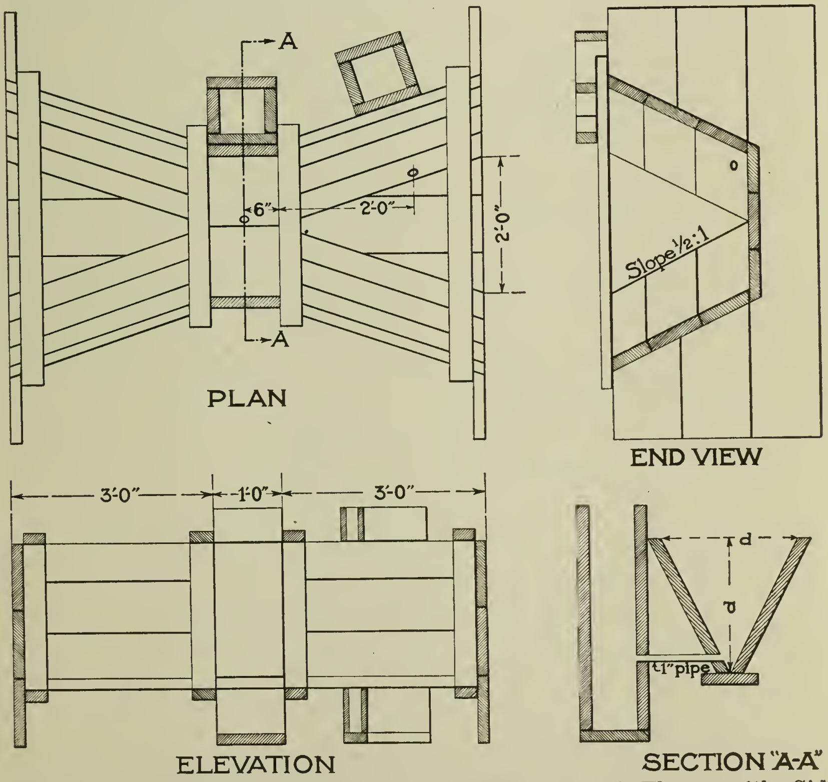

FIGURE 10.—Standard Plans for V-Notch Venturi Flume with Side Slopes ½ to 1.

The results of the calibration of the V-notch flume show that the loss of head is small for the usual conditions of operation, and that for any discharge the loss in head increases as the depth decreases. For convenience in determining the loss of head caused by the installation of the V-notch flume in a channel, the results are given in graphical form in Figure 11. To find the loss of head when the discharge and average depth are known, find the depth in the column on the left of the diagram, follow the horizontal line at this point until it intersects the given discharge curve, and then read the loss of head in feet at the bottom of the diagram directly beneath the intersection.

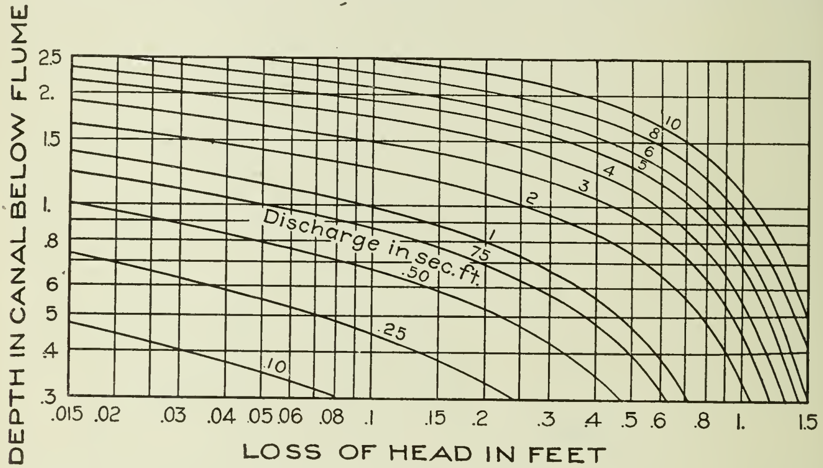

FIGURE 11.—Curves Showing the Loss of Head in Feet in a V-Notch Venturi Flume for Different Depths and Discharges.

The discharge diagram, Figure 19 was plotted from results computed from the formula:

$$Q = C \frac{H_b^2}{2} \sqrt{\frac{2g\,H_d}{1 - \frac{H_b^4}{(2\frac{2}{3} + H_a)^2 H_a^2}}}$$

Where Q = discharge in second feet,

$$C = 0.930 + (4.07 - 1.4\,H_a)\ (H_d - 0.05\,H_a - 0.04)^2 - \frac{0.362}{e^{80 H_d}},$$

H_a = upper head in feet,
H_b = throat head in feet,
$H_d = (H_a - H_b)$ = difference in head in feet,
e = 2.7183.

This formula is based on the results of the experiments made at the hydraulic laboratory at Fort Collins, Colorado, and the field laboratory at Bellvue, Colorado. To find the discharge from the diagram when the upper head, H_a, and the difference in head, H_d, are given, find the point where the horizontal line, thru the given difference in head on the left of the diagram, intersects the upper head curve, and read the discharge in second feet at the bottom of the diagram directly beneath this point.

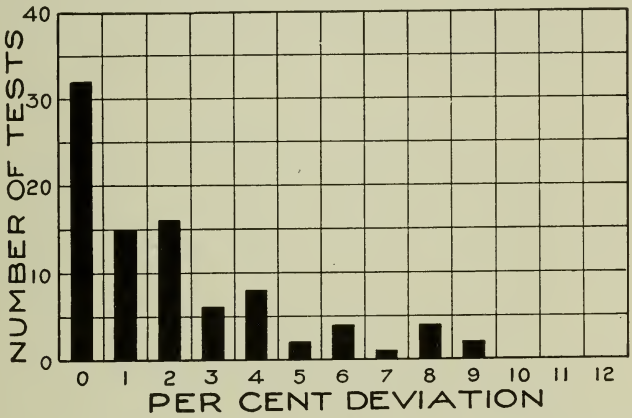

FIGURE 12.—Plot Showing the Deviation of the Computed Data from the Experimental Data for the V-Notch Venturi Flume.

The agreement of the results from the diagram with the experimental data is shown in Figure 12 which is similar to Figure 2 for the rectangular flumes.

The installation of the V-notch Venturi flume should not offer any practical difficulties. Either concrete or timber may be used. For concrete structures, see description of method given for rectangular flumes on page 14. If built of timber, it is recommended that commercial 2-inch plank be used. These planks should be surfaced on one side and so placed that this smooth surface would form the inside of the flume. Care should be exercised in properly fitting the sides to the throat section so as to make the edge of the two surfaces or joint smooth and regular. The pipe connection to the throat gage well should be made as shown in drawing, and approximately 2 inches above the bottom point of the throat. The pipe connection for the upstream or upper gage well should be placed horizontally and at right angles to the edge of the plank, also approximately 2 inches above the floor. These pipes should not extend beyond the inside surface of the sides of the structure. The floor of the flume should be level in both directions and placed so that the floor line will be on the grade of the channel. The size of the gage wells is not important; however they should be of sufficient size for cleaning purposes. If made of 2-by 12-inch plank and built as shown in the plan, the opening will be approximately 8 by 10 inches. The depth should be sufficient to reach at least one-half foot below the floor of the flume and a bottom should be provided for both wells. When set in position, they should be vertical and close to the structure, with the tops of the wells at the same elevation. Covers for the wells may be provided if found necessary.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and cooperation of the Jackson Ditch Company of La Porte, Colorado, in permitting the use of their diversion dam and head works in connection with the experiments conducted at the Bellvue laboratory.

SUMMARY

The Venturi flume is intended to meet those conditions for which the standard weir or other measuring devices are not suited, the most important application being where sufficient head is not available for other types of measuring devices.

The accuracy of the Venturi flume is sufficient to meet ordinary requirements and by actual computation it has been shown that, for all sizes of rectangular flumes investigated with discharges ranging from less than 1 second foot to nearly 400 second feet, 94 per cent of all tests show an error in discharge of 5 per cent or less.

A similar comparison for the V-notch flume shows that for discharges ranging from 0.1 to 10 second feet, 70 per cent of all the tests show an error of 2 per cent or less.

In order to obtain the best results from the rectangular Venturi flume, it is recommended that four gage wells be installed, and that the mean reading be used in determining the discharge.

Where the installation of a flume is made with the intention of using a recording instrument, a special arrangement of float wells is necessary, and also provision must be made for connecting these two wells with those on the opposite side of the flume.

Frequent testing of the sensitiveness of the gage wells is advisable. Cleaning of the wells of silt or sand should be done when found necessary, and this can best be accomplished by a false bottomed bucket or can, rigidly fixed to a long rod or wooden handle.

Scales or gages attached to the inside surface of the flume for determining the head are not sufficiently accurate for general purposes.

Due to the nature of the law of flow through the Venturi flume, the accuracy increases as the difference in head increases; also the per cent of error in making the reading is decreased when the difference in head is great. Consequently, it is advisable, if the head is available, to operate the flume with the greatest difference in head possible.

The application of the general discharge formulas, as given for the Venturi flume, is not recommended for determining discharges for flumes having throat widths or depths beyond the limits of those shown in the diagrams; however, if these expressions are applied, the results will be only approximations.

Concrete structures are recommended, but timber may be used if the structures are well braced to insure stability.

The logarithmic discharge diagrams are used in exactly the same manner as an ordinary co-ordinate chart; however, care must be used in picking off the values because of the fact that the intervals of equal value decrease as the quantities increase.

Changing the velocity or increasing the depth of water below the flume does not effect the utility of the device. All changes are automatically taken care of by the variation in the gage heights.

TABLE 1.—PER CENT OF ERROR FOR RECTANGULAR FLUMES, DUE TO OBSERVING HEADS ON ONE SIDE ONLY.

One Foot Throat			
H_a	H_d	Standard Discharge	% Error
1.000	0.133	2.60	1.23
1.500	.041	2.60	2.77
2.000	.019	2.58	3.56
2.500	.011	2.56	5.35
3.000	.009	2.54	3.57
1.500	.208	5.06	1.64
2.000	.088	5.10	2.42
2.500	.046	5.10	2.20
3.000	.033	5.10	3.80
3.500	.026	5.11	3.96
4.000	.019	5.12	3.07
2.000	.707	10.20	0.00
2.500	.280	10.24	1.15
3.000	.166	10.21	2.39
3.500	.114	10.18	2.76
4.000	.083	10.17	2.06
3.000	.503	15.30	0.44
3.500	.318	15.30	1.25
4.000	.212	15.30	1.42

Two Foot Throat			
H_a	H_d	Standard Discharge	% Error
1.000	0.127	5.07	3.35
1.500	.041	5.10	4.90
2.000	.024	5.10	5.75
2.500	.014	5.10	4.32
1.500	.252	10.35	3.06
2.000	.095	10.24	6.37
2.500	.056	10.23	5.67
3.000	.039	10.25	5.73
3.500	.028	10.26	6.36
4.000	.022	10.26	7.62
2.000	.284	15.36	3.38
2.500	.143	15.41	5.24
3.000	.095	15.43	6.25
3.500	.067	15.40	5.85
4.000	.047	15.36	4.54
2.500	.291	20.30	3.14
3.000	.166	20.30	4.79
3.500	.115	20.32	5.71
4.000	.083	20.33	6.01
2.500	.588	25.31	0.00
3.000	.299	25.31	2.94
3.500	.195	25.31	3.69
4.000	.136	25.39	3.93
3.000	.546	30.22	0.77
3.500	.345	30.22	1.66
4.000	.238	30.30	3.02

Three Foot Throat			
H_a	H_d	Standard Discharge	% Error
1.000	0.052	5.12	6.64
1.500	.019	5.22	6.41
2.000	.010	5.22	7.01
2.500	.006	5.11	7.15
3.000	.004	5.11	7.83
1.500	.091	10.20	5.41
2.000	.044	10.20	7.97
2.500	.029	10.47	8.87
3.000	.020	10.20	9.62
3.500	.014	10.44	6.61
1.500	.240	15.00	4.60
2.000	.104	15.44	7.32
2.500	.063	15.35	8.20
3.000	.044	15.30	8.90
3.500	.031	15.35	9.19
4.000	.022	15.60	10.31
2.000	.200	20.37	4.92
2.500	.106	20.31	6.80
3.000	.068	20.40	8.23
3.500	.052	20.30	8.97
4.000	.038	20.20	8.86
2.000	.410	25.60	2.02
2.500	.187	25.52	5.25
3.000	.116	25.50	6.67
3.500	.080	25.50	7.02
4.000	.058	25.60	7.23
2.500	.302	30.45	3.18
3.000	.176	30.20	3.88
3.500	.118	30.50	5.32
4.000	.087	30.00	4.98
3.000	.822	50.10	0.42
3.500	.451	50.00	3.68
4.000	.300	50.00	6.82
5.000	.174	50.00	9.00
6.000	.118	50.00	9.42
7.000	.087	50.00	8.24
8.000	.064	50.00	8.12

Five Foot Throat			
H_a	H_d	Standard Discharge	% Error
1.000	0.063	10.0	9.93
1.500	.025	10.0	8.85
2.000	.016	10.0	6.02
2.500	.334	50.1	8.88
3.000	.203	50.1	11.25
3.500	.142	50.2	12.43
4.000	.105	50.1	11.77
5.000	.065	50.1	11.02
6.000	.044	50.0	9.56
7.000	.032	50.0	9.10
8.000	.027	49.9	10.10
3.000	.510	70.2	6.91
3.500	.316	70.1	9.63
4.000	.223	70.2	10.30
5.000	.132	70.0	10.10
6.000	.088	70.0	10.05
7.000	.064	70.0	10.42
8.000	.049	70.0	10.15
4.500	1.308	149.2	1.64
5.000	.902	150.3	6.11
6.000	.504	150.6	9.84
7.000	.332	150.6	11.68
8.000	.242	150.4	12.66
7.000	2.090	299.0	1.02
8.000	1.312	299.0	4.39
9.000	.930	299.0	5.63

TABLE II.— CONVERSION TABLE, SECOND FEET, TO COLORADO STATUTORY INCHES, BASED ON ONE SECOND FOOT, EQUALS 38.4 MINER'S INCHES.

Second Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	...	4	8	12	15	19	23	27	31	35
1	38	42	46	50	54	58	61	65	69	73
2	77	81	84	88	92	96	100	104	108	111
3	115	119	123	127	131	134	138	142	146	159
4	154	157	161	165	169	173	177	180	184	188
5	192	196	200	204	207	211	215	219	223	227
6	230	234	238	242	246	250	253	257	261	265
7	269	273	276	280	284	288	292	296	300	303
8	307	311	315	319	323	326	330	334	338	342
9	346	349	353	357	361	365	369	372	376	380
10	384	388	392	396	399	403	407	411	415	419

TABLE III.—DECIMALS OF A FOOT FOR EACH 1/16 OF AN INCH.

Inches	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/1	7/8	15/16
0	.000	.005	.010	.016	.021	.026	.031	.037	.042	.047	.052	.057	.063	.068	.073	.078
1	.083	.089	.094	.099	.104	.109	.115	.120	.125	.130	.135	.141	.146	.151	.156	.162
2	.167	.172	.177	.182	.188	.193	.198	.203	.208	.214	.219	.224	.229	.234	.240	.245
3	.250	.255	.260	.266	.271	.276	.281	.287	.292	.297	.302	.307	.313	.318	.323	.328
4	.333	.339	.344	.349	.354	.359	.365	.370	.375	.380	.385	.390	.396	.401	.406	.412
5	.417	.422	.427	.432	.438	.443	.448	.453	.458	.464	.469	.474	.479	.484	.490	.495
6	.500	.505	.510	.516	.521	.526	.531	.537	.542	.547	.552	.557	.563	.568	.573	.578
7	.583	.589	.594	.599	.604	.609	.615	.620	.625	.630	.635	.641	.646	.651	.656	.662
8	.667	.672	.677	.682	.688	.693	.698	.703	.708	.714	.719	.724	.729	.734	.740	.745
9	.750	.755	.760	.766	.771	.776	.781	.787	.792	.797	.802	.807	.813	.818	.823	.828
10	.833	.839	.844	.849	.854	.859	.865	.870	.875	.880	.885	.891	.896	.901	.906	.912
11	.917	.922	.927	.932	.938	.943	.948	.953	.958	.964	.969	.974	.979	.984	.990	.995

UNITS OF MEASURE

The Cubic Foot per Second, called second-foot, is a unit of measure for flowing water. When a stream discharges 1 cubic foot of water in one second, there is a second-foot flow.

The Acre-Foot, is a unit of measure for standing water, and is that volume which will cover one acre one foot deep. An acre-inch is one-twelfth of an acre-foot, or the volume which will cover one acre to a depth of one inch.

The Miner's Inch is unsatisfactory, and rapidly losing favor as a unit for measuring water, because it is not a definite quantity. It varies with the conditions under which it is used, and is therefore being replaced by the second-foot.

TABLE OF HYDRAULIC EQUIVALENTS.

One cubic foot equal 7.48 gallons, or approximately 7½ gallons.

One cubic foot of water weighs approximately 62½ pounds.

One cubic foot per second equals 448.83 gallons per minute, or approximately 450 gallons per minute.

One cubic foot per second flowing for 1 hour, equals approxmately 1 acre-inch.

One cubic foot per second, flowing for 12 hours, equals approximately 1 acre-foot.

One cubic-foot per second, flowing for 24 hours, equals approximately 2 acre-feet.

One acre-foot equals 43,560 cubic feet, equals 325,851 gallons.

One million cubic feet equals 22.95 acre-feet.

In Colorado it has been generally assumed that 1 Miner's inch (Statutory inch) equals 1-38.4 of one cubic foot per second.

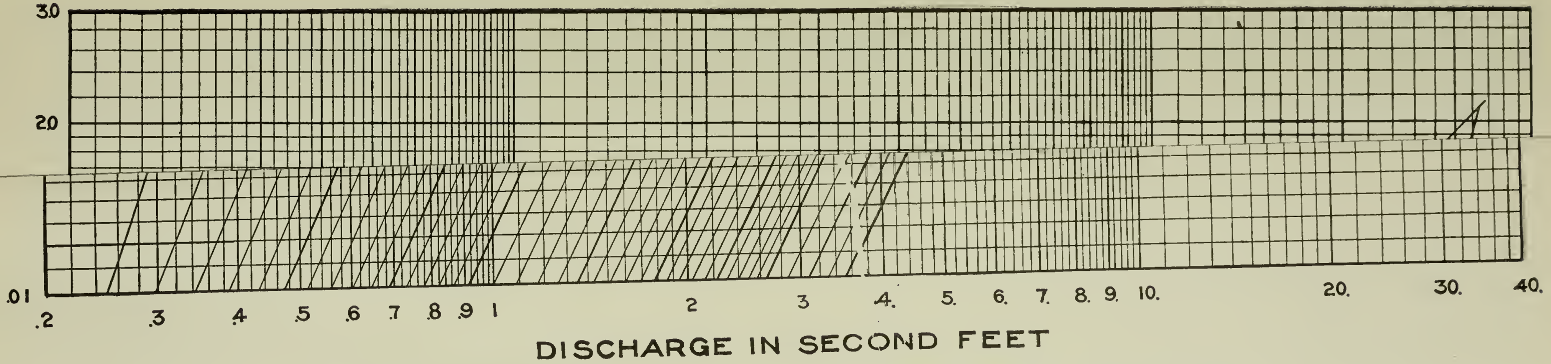

FIGURE 13.—Discharge Diagram for the One Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

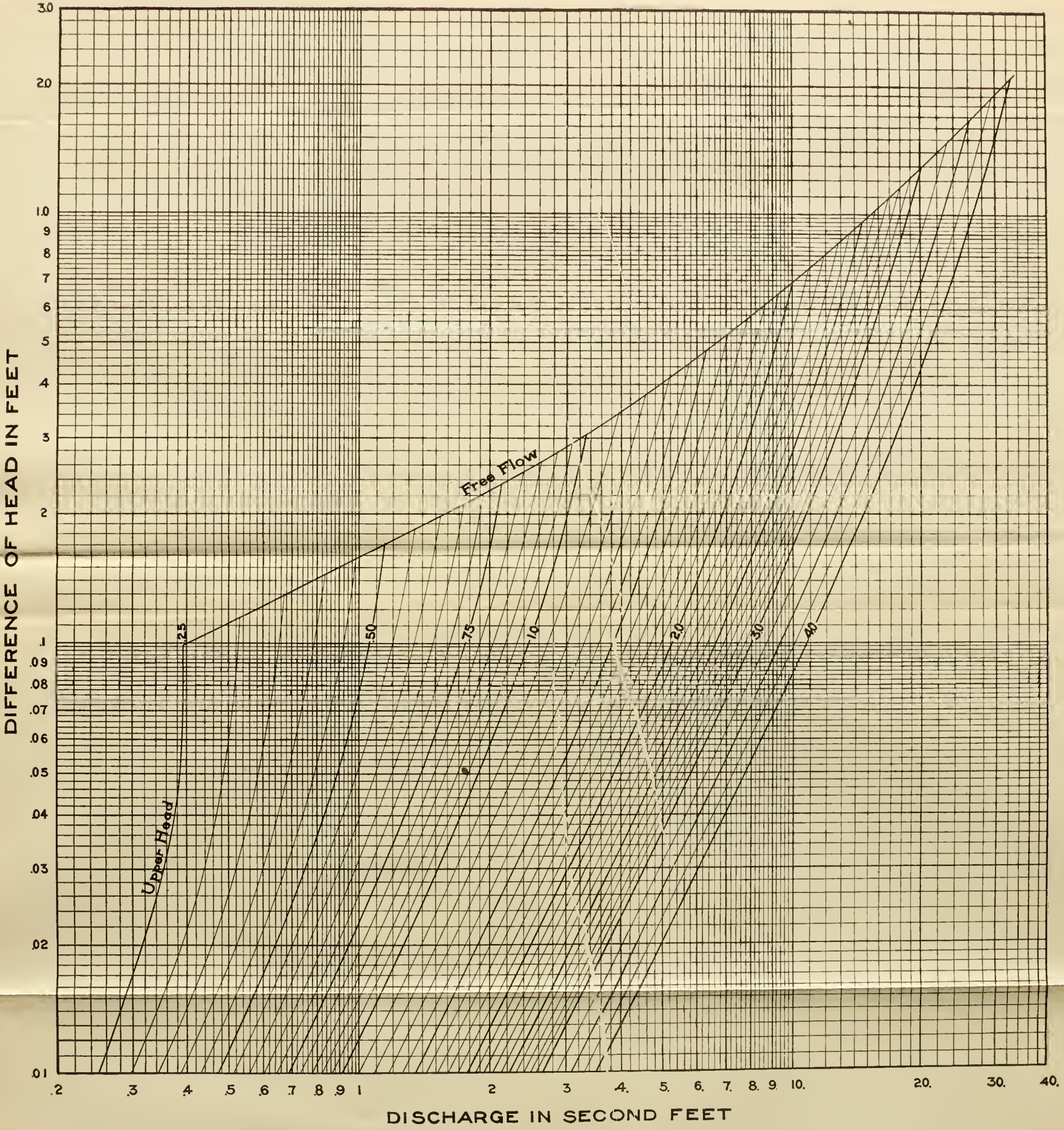

FIGURE 13.—Discharge Diagram for the One Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

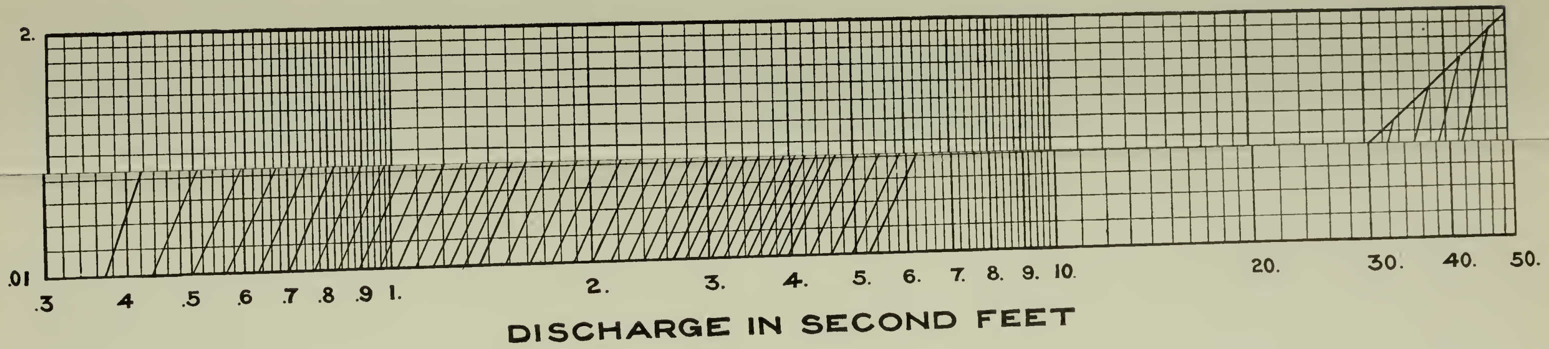

FIGURE 14.—Discharge Diagram for the One and One-Half Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on page 11.

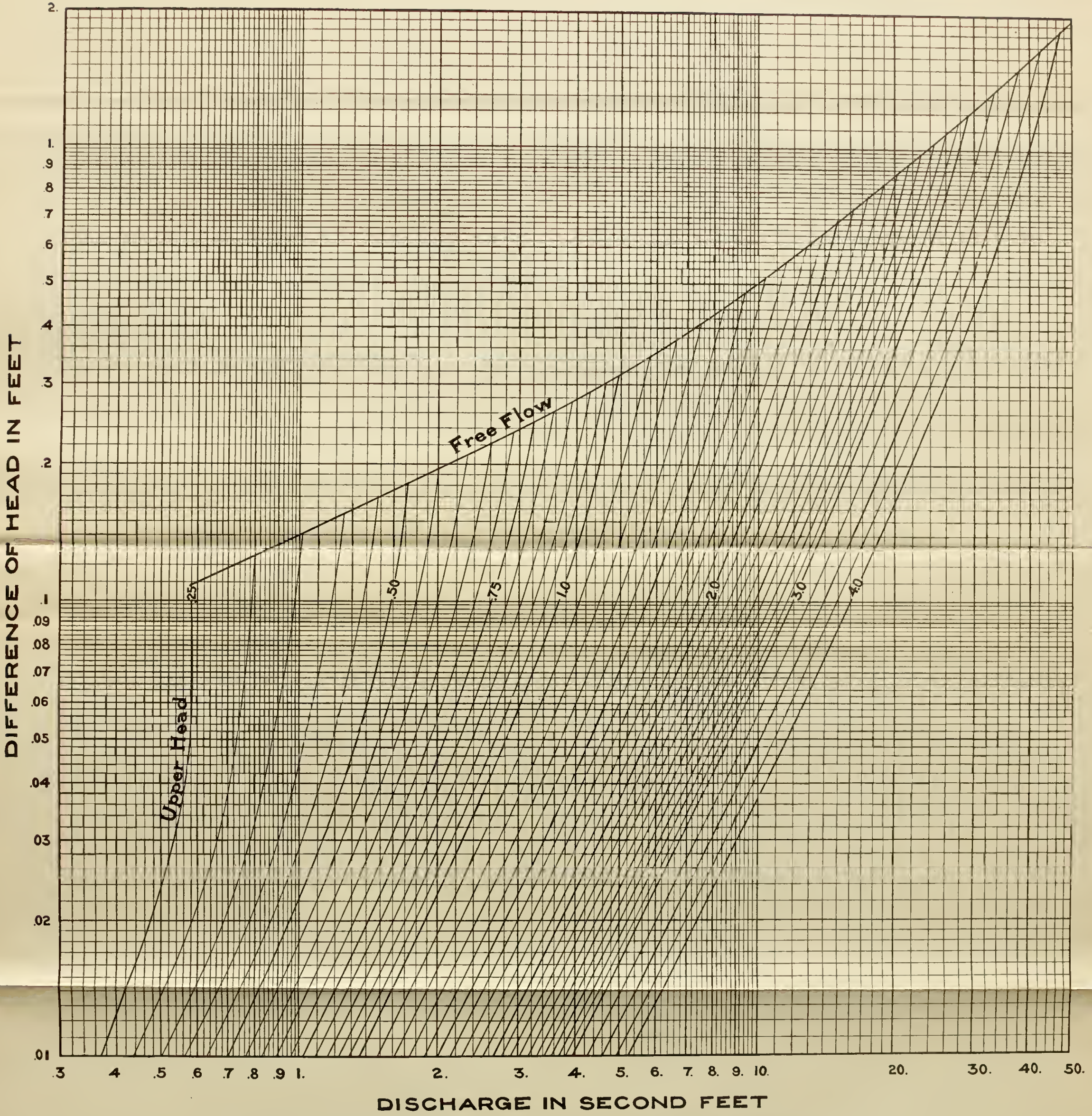

FIGURE 14.—Discharge Diagram for the One and One-Half Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on page 11.

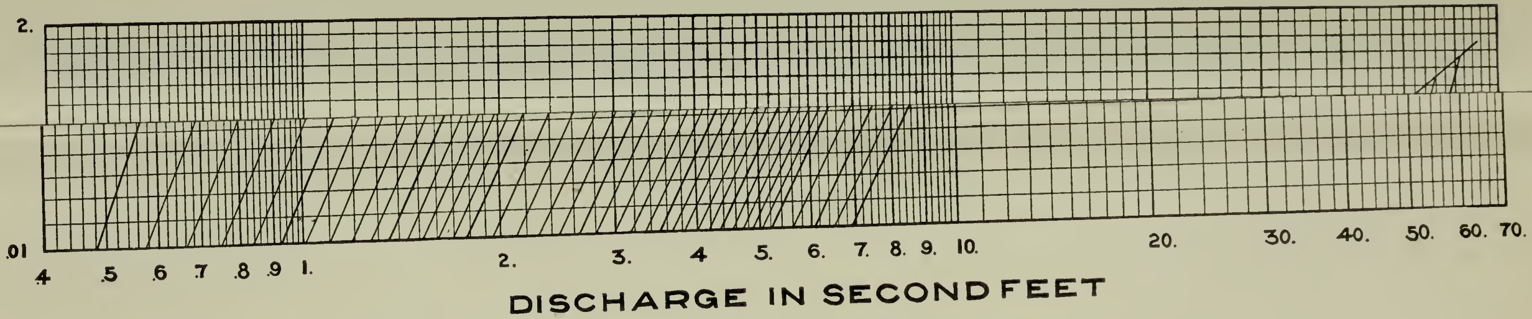

FIGURE 15.—Discharge Diagram for the Two Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

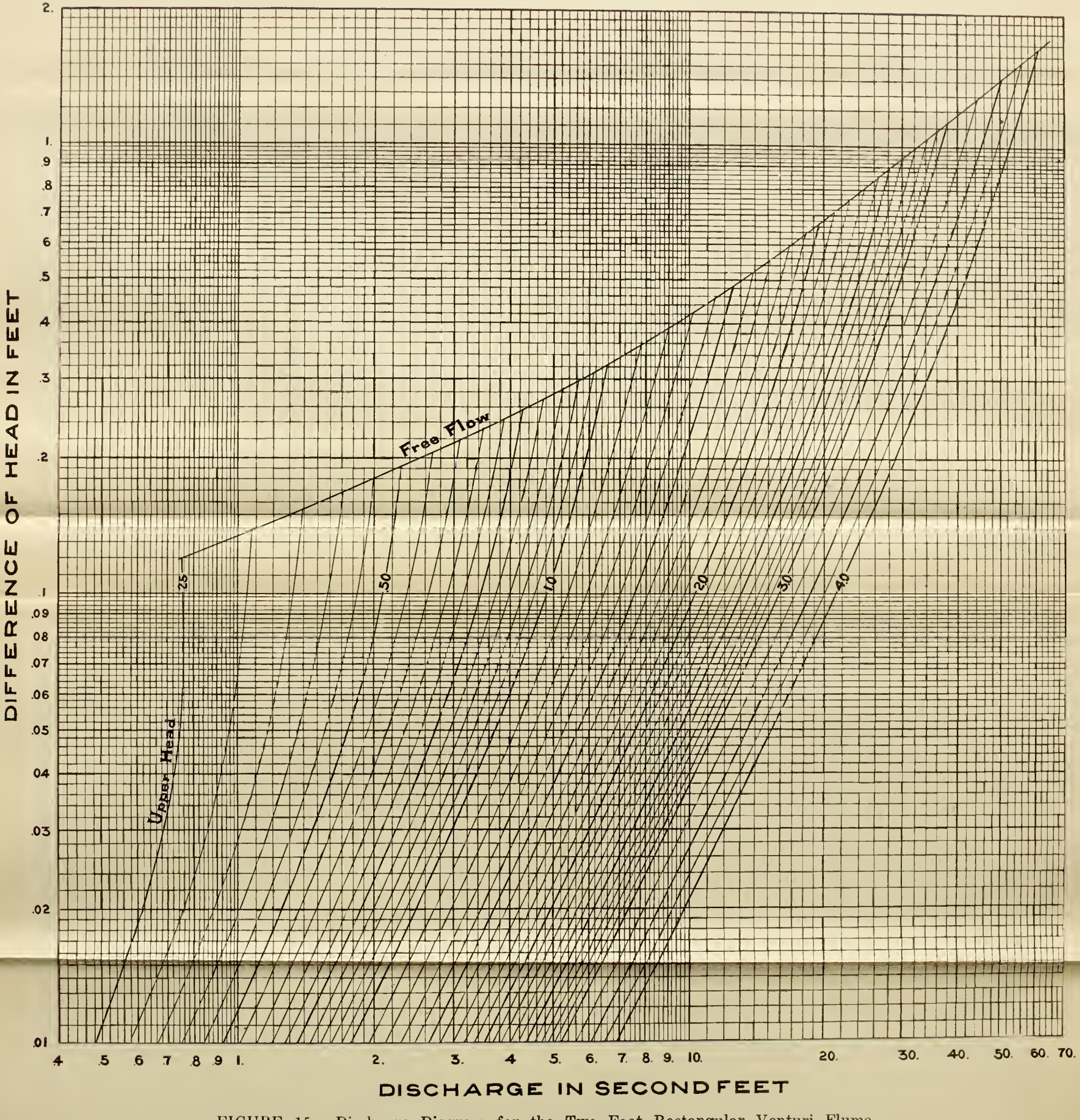

FIGURE 15.—Discharge Diagram for the Two Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

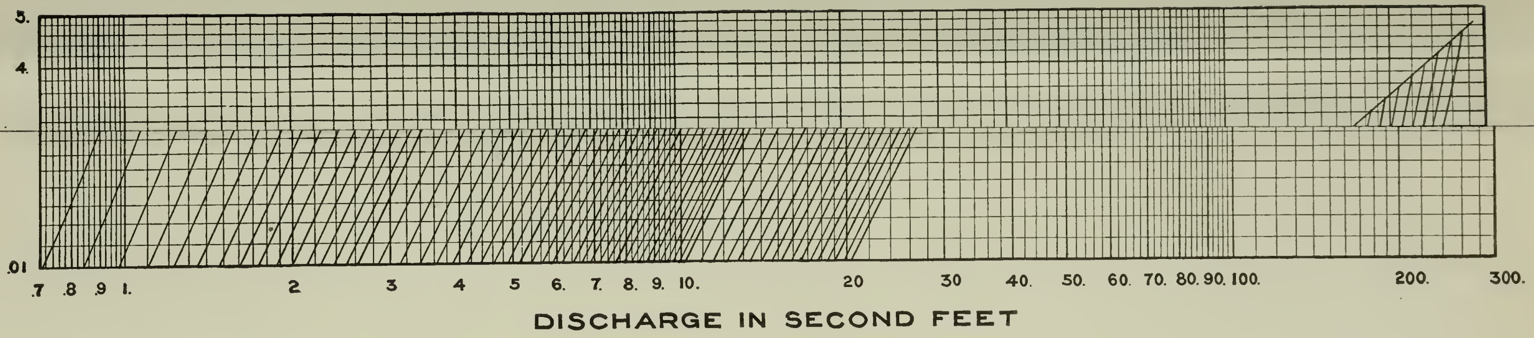

FIGURE 16.—Discharge Diagram for the Three Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

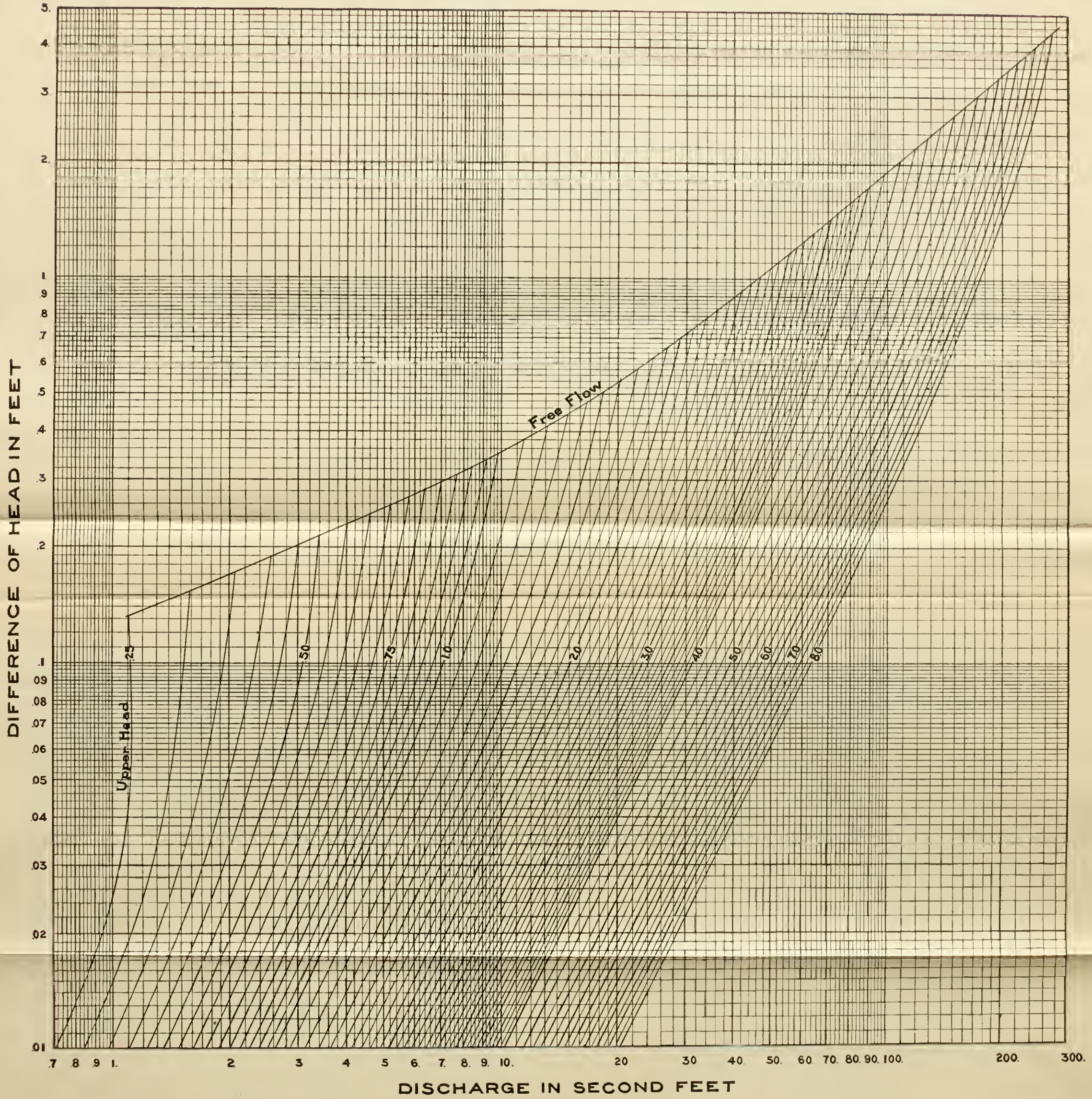

FIGURE 16.—Discharge Diagram for the Three Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

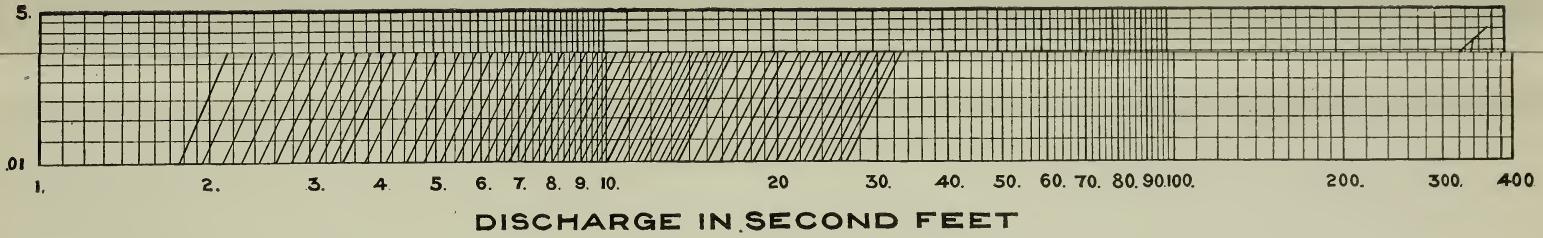

FIGURE 17.—Discharge Diagram for the Four Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

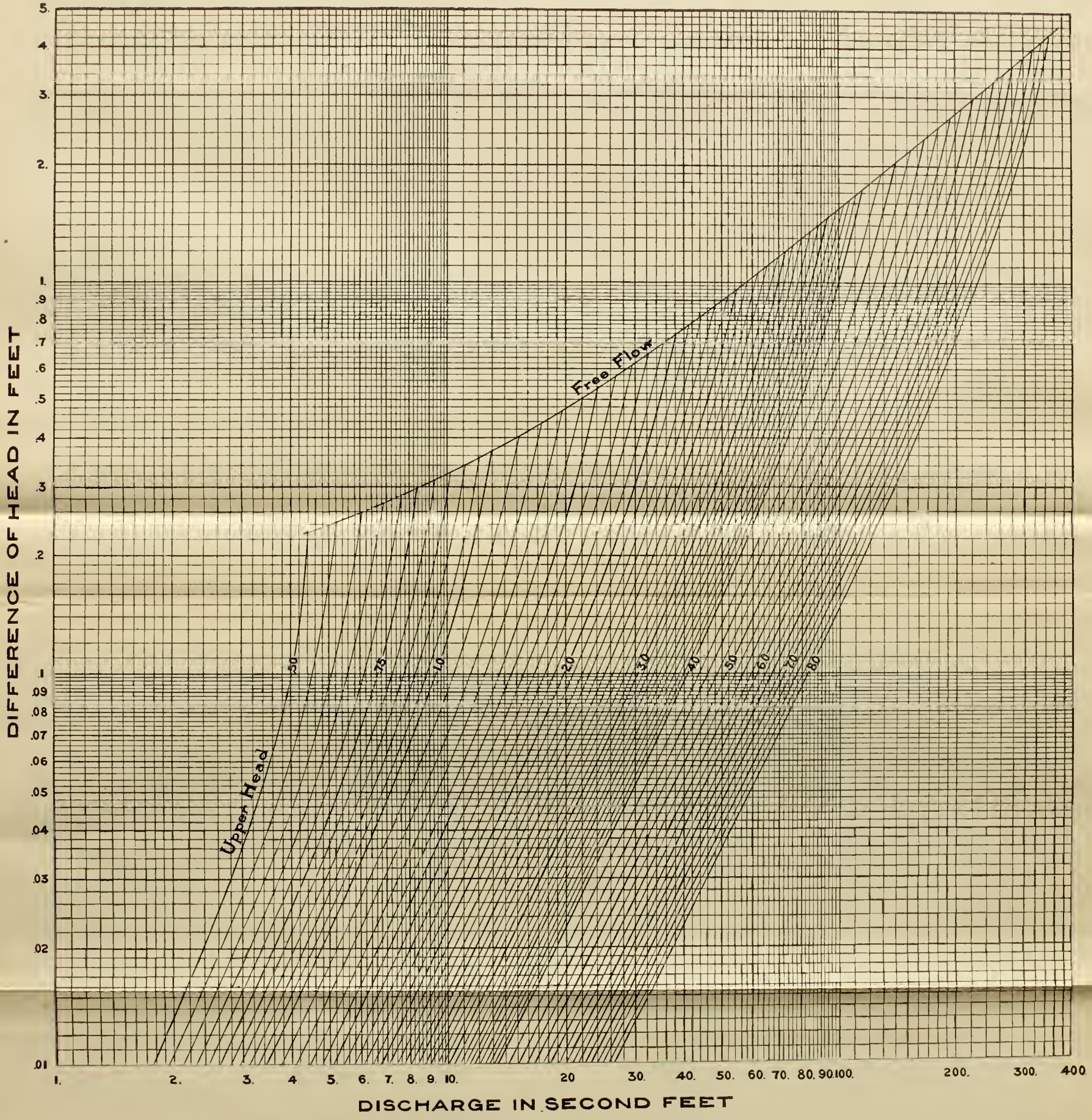

FIGURE 17.—Discharge Diagram for the Four Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

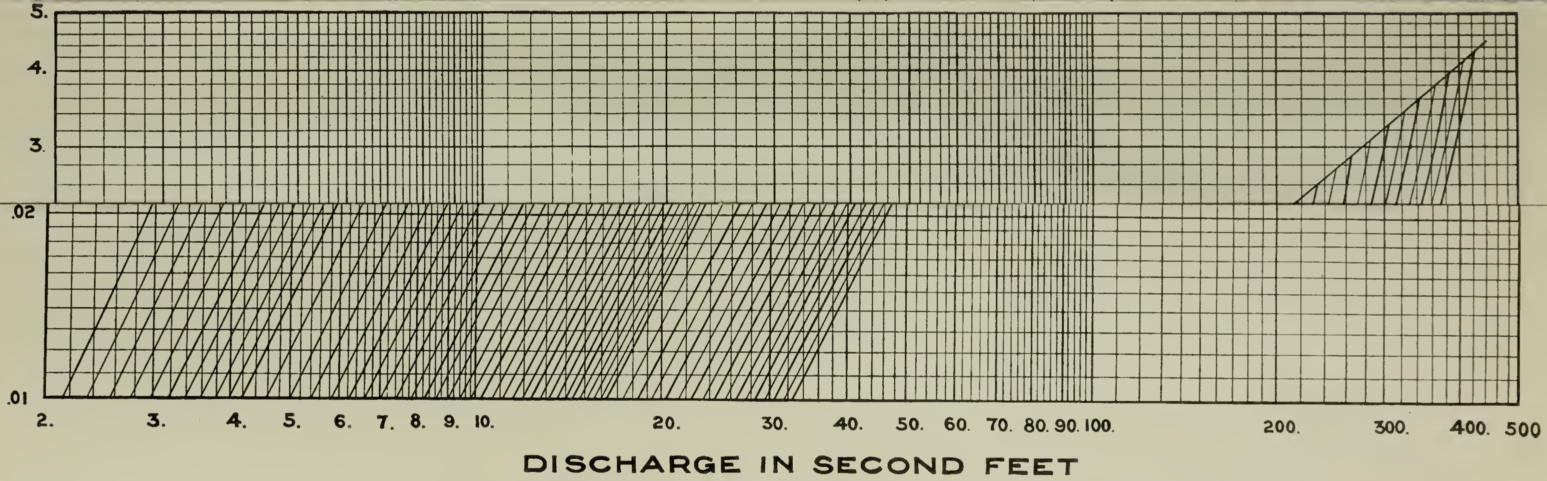

FIGURE 18.—Discharge Diagram for the Five Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

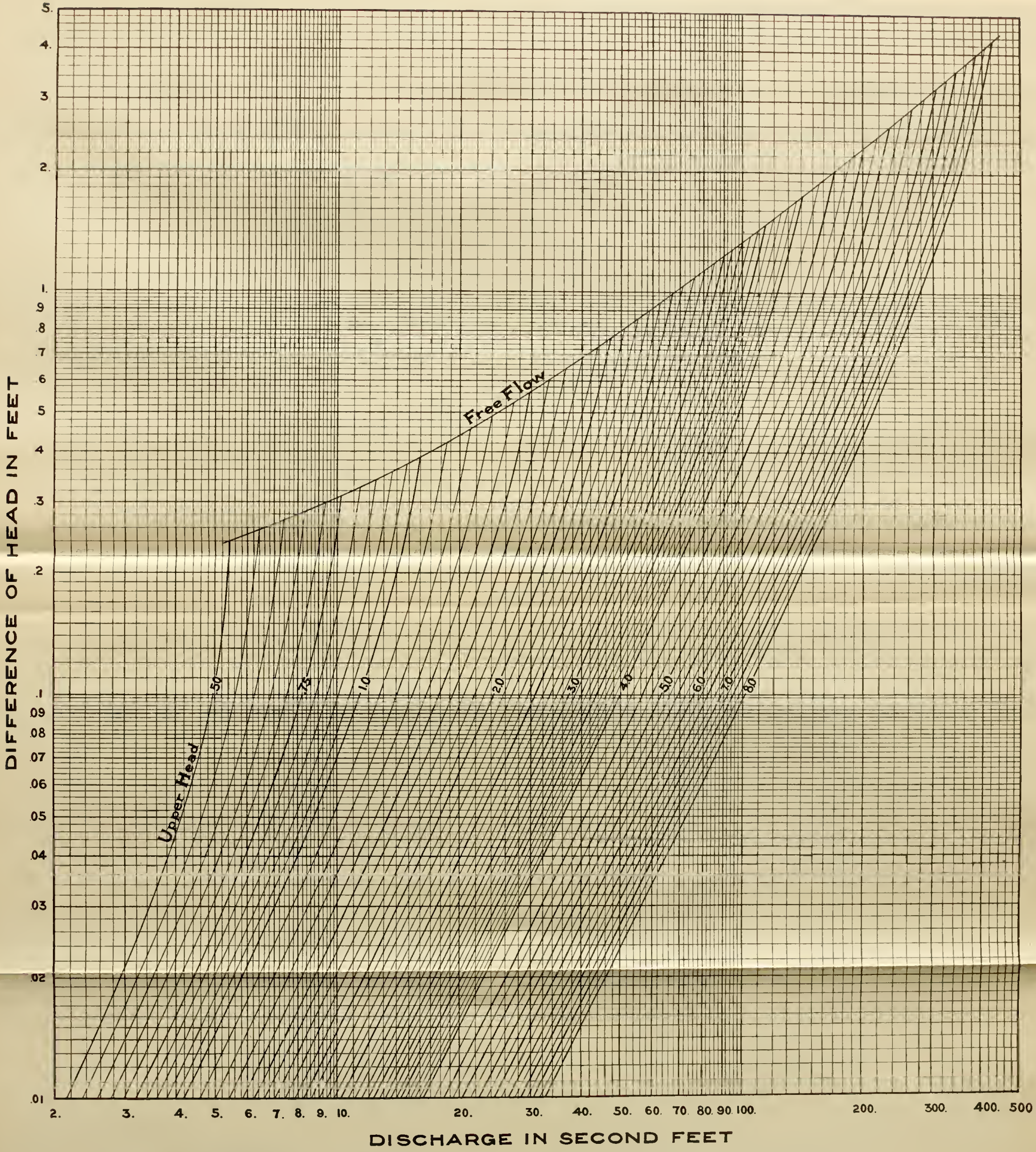

FIGURE 18.—Discharge Diagram for the Five Foot Rectangular Venturi Flume, Plotted from Results Computed by the Formula Given on Page 11.

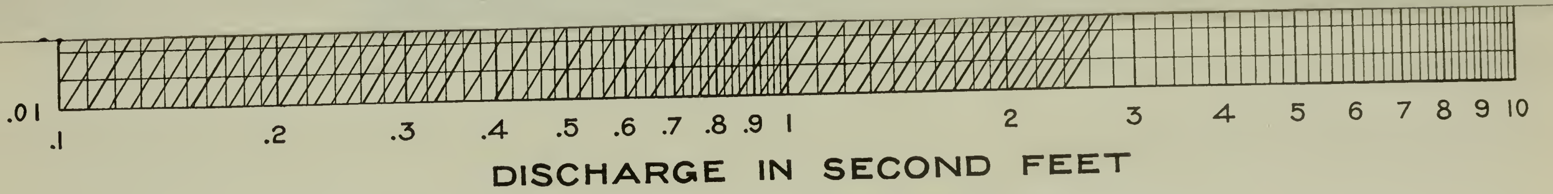

FIGURE 19.—Discharge Diagram for the V-Notch Venturi Flume, Plotted from Résults Computed by the Formula Given on Page 22.

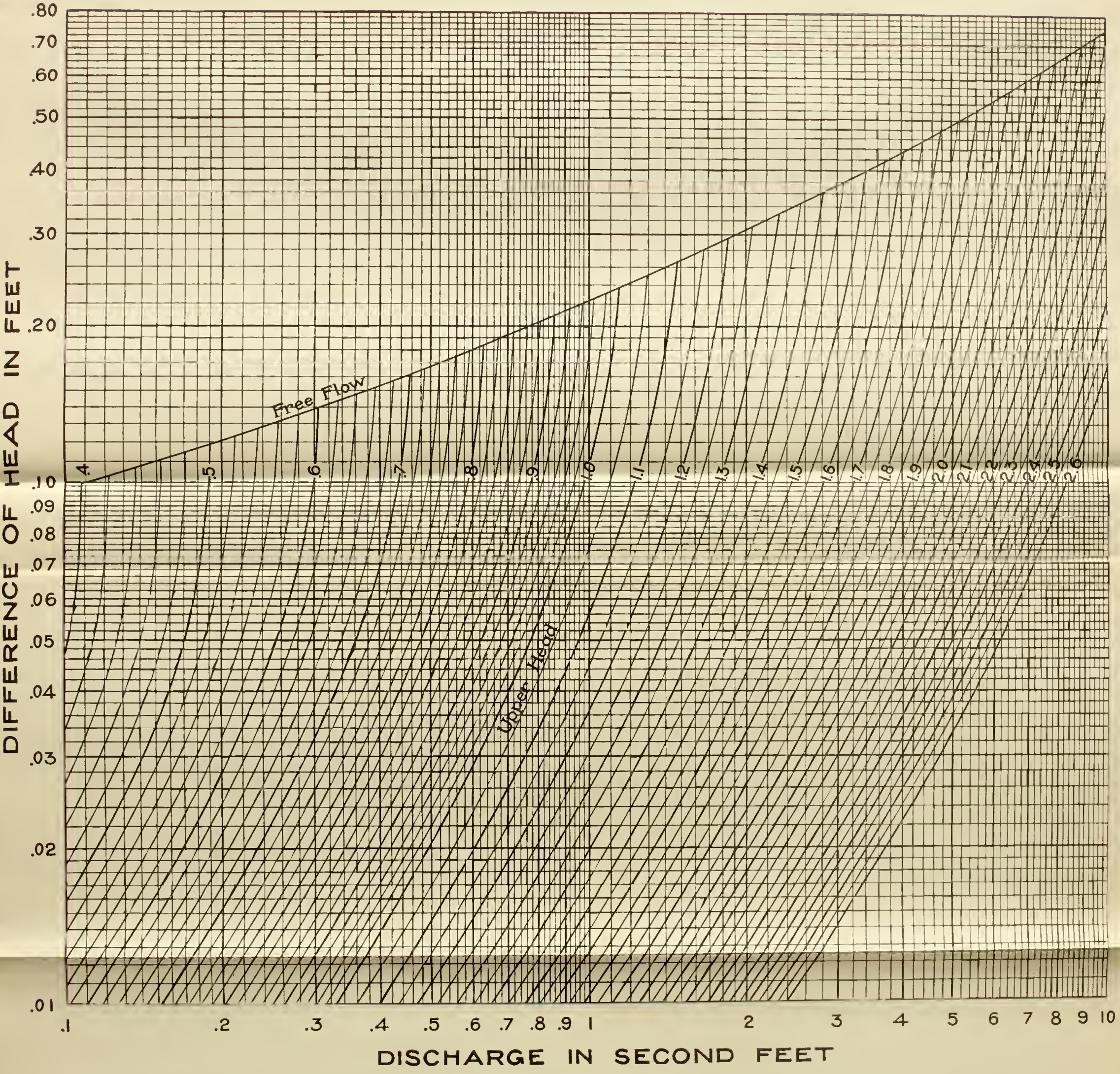

FIGURE 19.—Discharge Diagram for the V-Notch Venturi Flume, Plotted from Results Computed by the Formula Given on Page 22.

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Bulletin 266 April, 1921

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

BEET BY-PRODUCTS FOR FATTENING LAMBS

By E. J. MAYNARD
Specialist in Animal Investigations

Lambs in a Northern Colorado Feed Lot, Season of 1920-21.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1921

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The Colorado Agricultural College

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BEET BY-PRODUCTS FOR FATTENING LAMBS

E. J. Maynard, Specialist in Animal Investigations

CONCLUSIONS

Beet Molasses becomes more valuable in the lamb fattening ration as the cost of corn increases. In the trial it decreased the feed cost 11 cents per head but increased the labor cost two cents per head, increased the shrink 0.5 per cent and decreased the selling price 10 cents per hundred. Beet molasses fed in this test with corn and alfalfa decreased the loss 4 cents per lamb.

Barley and Oats, which sold at higher prices per hundred than corn, did not prove to be as efficient as corn when fed with molasses and alfalfa.

Dried-Molasses-Beet-Pulp although not equal to corn, when fed alone with alfalfa, showed very favorable results when mixed half and half with corn. This mixture when compared to straight corn apparently shows the dried pulp more than equal to corn pound for pound in putting on gains. The dried pulp decreased the cost of feed 21 cents per head, and although it increased the shrink 1.5 per cent, at the same time it increased the selling price of the lambs 25 cents per hundred and decreased the loss per head 43 cents. A mixture of equal parts dried pulp and corn proved more economical than a combination consisting of 2-3 corn and 1-3 dried pulp.

Wet Beet Pulp:

The wet pulp fed lambs made the heaviest gains and at the cheapest feed cost. Their selling price was 10 cents per hundred below the check lot and 35 cents below the corn and dried pulp lots, so that with their heavier labor cost they lost 18 cents more per head than did the favorably fed corn and dried pulp lot. It is possible that the greater size of the wet pulp lambs was in part responsible for the lower selling price, they being heavier lambs. Had they been marketed earlier, it is probable that they would have commanded the top price in which case they would have been the most economically fed lot. The advantages of wet pulp depend largely on length of haul from factory and labor cost.

INTRODUCTION

To know the most economical rations and the comparative value of available Colorado feeds is a matter of extreme importance to the lamb feeder at the present time.

Narrow margins may be expected in the future, and it is extremely important that the feeder "leave no stone unturned" in securing the cheapest gains possible.

By-products from the manufacture of beet sugar play an important part in the lamb feeding industry of Colorado.

There have been many inquiries regarding the value of these by-products, and the best combinations to use in obtaining rapid and economical gains.

Wet pulp is being used more extensively than ever before in fattening lambs. Dried molasses beet pulp and beet molasses are available at low prices.

The results secured from the feeding test carried on this year are herein presented for the information of Colorado feeders.

Where the Experiment Was Conducted. Lamb Feeding Lots, Colorado Experiment Station.

OBJECTS OF THE TEST

1. To determine the value of beet molasses when fed in limited quantity with grain and alfalfa.

2. To test the comparative value of corn, barley and oats when fed along with beet molasses and alfalfa.

3. To compare dried molasses beet pulp with corn.

4. To determine an economical combination of dried molasses beet pulp and corn.

5. To test the value of wet pulp in partially replacing corn.

ANIMALS USED

The lambs used in the test were bought on the Denver market, October 27th. They came from southern Colorado, and were of good grade, representing the average type of feeder lamb found in the northern Colorado feed yards. About forty per cent were of fine wool foundation while the rest showed the Hampshire or Shropshire characteristics, having black faces and blocky forms.

METHODS USED IN TEST

The lambs were divided into eight lots of thirty-two each, care being taken to equalize the pens with regard to weight, sex, breeding and condition. The lots were kept in adjoining pens running north and south enclosed by a four-foot board fence, which with the hay self feeders served as a wind-break. Block salt and fresh water were kept before the lambs at all times.

At the beginning and end of the test, weights were taken on three consecutive days, the average of these being used. Individual weights were secured at the end of each thirty-day period.

RATIONS FED

Lot 1—Corn, alfalfa.
Lot 2—Corn, beet molasses, alfalfa.
Lot 3—Barley, beet molasses, alfalfa.
Lot 4—Oats, beet molasses, alfalfa.
Lot 5—Dried-molasses-beet-pulp, alfalfa.
Lot 6—Dried-molasses-beet-pulp 1-2, corn 1-2, alfalfa.
Lot 7—Dried-molasses-beet-pulp 1-3, corn 2-3, alfalfa.
Lot 8—Corn, wet pulp, alfalfa.

In all cases whole grain was fed. The lambs were fed twice daily, except for alfalfa which was self fed. Starting with one-fourth pound per head per day, thirty-eight days were taken to get the lambs in Lot 1 up to a pound of grain.

Molasses was fed by pouring it along the trough, and spreading the grain on it.

Starting with one-tenth pound of molasses per head, forty days were taken to get the lambs up to one-fourth pound.

The wet pulp was fed on the ground through panels.

FEEDS USED

Shelled Corn:

The shelled corn used was a No. 3 mixed.

Barley:

This grain was secured from local dealers and was No. 3 (warehouse grade). It weighed 44 pounds per bushel, was somewhat off in color and contained considerable foreign matter consisting mostly of other grains.

Oats:

The oats used in the test were Nebraska grown weighed 32.5 pounds per bushel. They were graded No. 4, but would have graded higher except that they contained impurities represented by other grains. Their weight was brought up by these impurities.

Dried-Molasses-Beet-Pulp:

This feed is made by mixing and drying wet beet pulp and beet molasses so that 25 per cent of the dried substance is molasses. It was secured from the sugar company at a net price of $18.40 per ton which is the regular net market price.

Beet Molasses:

The molasses was hauled from the factory in a metal tank. Wooden tanks have generally proved unsatisfactory because hot molasses does not expand wood as water does, and will leak out where water will not. The present price of the beet molasses is $15.00 per ton.

Wet Beet Pulp:

Green pulp was fed during the first half of the test while during the last half the pulp was fairly well ripened.

An Easy Way to Feed Wet Beet Pulp—And the Lambs Like It.

Alfalfa:

All hay used was grown on the College farm and was of good quality. First, second and third cutting was fed according to the stack open at time of hauling. The lambs wasted more of the first cutting hay pulling out the heavy stalks and stems.

ANALYSIS OF FEEDS USED IN TEST

By E. L. Scott, Chemist

(Percent)

	Moisture	Crude Protein	Carbohydrates		Fat	Ash
			N. F. E.	Crude Fibre		
Shelled Corn	14.81	9.45	67.71	1.28	5.55	1.20
Whole Barley	14.11	12.97	61.77	6.05	2.60	2.50
Whole Oats	11.75	12.15	56.25	10.90	5.30	3.65
Dried Molasses Beet Pulp	11.36	8.84	59.94	14.24	.....	5.62
Beet Molasses	19.80	9.30	60.50	.....	.....	10.40
Wet Beet Pulp	88.07	1.80	6.78	2.83	.13	.39
Alfalfa	9.50	14.95	36.96	27.21	1.83	9.55

The moisture analysis on wet pulp represents an average of tests during the feeding trial. Moisture varied from 90.2% to 87.1%.

WEIGHTS, FEED REQUIREMENTS AND FEED COST OF GAINS

8 Lots of 32 Lambs Each Fed 93 Days, November 28, 1920 to March 1, 1921
All Weights in Pounds
(On basis of one average Lamb)

Lot Number	1	2	3	4	5	6	7	8
Ration Fed*	Corn	Corn Molasses	Barley Molasses	Oats Molasses	Dried Molasses Beet Pulp	Corn (½) Dried Molasses Beet Pulp (½)	Corn (2-3) Dried Molasses Beet Pulp (1-3)	Corn, Wet Pulp
Initial Weight Ft. C.	70.7	71.0	71.1	71.1	71.2	70.8	70.9	71.3
Final Weight Ft. C.	101.8	103.3	100.3	101.2	100.4	103.5	102.3	105.5
Total Gain 93 Days	31.1	32.3	29.2	30.1	29.2	32.7	31.4	34.2
Daily Gain	.334	.347	.314	.323	.314	.351	.338	.367
Daily Feed								
Shelled Corn	1.03	.76				.52	.69	.52
Whole Barley			.76					
Whole Oats				.76				
Dried Molasses, Beet Pulp					1.03	.52	.34	
Beet Molasses		.30	.30	.30				
Wet Beet Pulp								.556
Alfalfa	2.50	2.53	2.54	2.61	2.45	2.50	2.67	2.17
Feed for 100 lbs. Gain								
Shelled Corn	309.4	219.6				147.4	203.7	141.3
Whole Barley			243.0					
Whole Oats				236.4				
Dried Molasses Beet Pulp					328.1	147.5	101.6	
Beet Molasses		85.8	94.9	92.3				
Wet Beet Pulp								1514.2
Alfalfa	749.0	726.5	808.1	808.9	781.4	711.5	790.7	591.5
Feed Cost per 100 lbs. Gain	9.57	8.84	10.18	10.06	8.64	8.47	9.38	7.11

*All Lots Self-fed Alfalfa Hay.

Shelled Corn	$1.35 Cwt.	Dried Molasses Beet Pulp	$18.40 per Ton
Barley	1.50 Cwt.	Wet Pulp	1.25 per Ton
Oats	1.50 Cwt.	Alfalfa	14.40 per Ton
Molasses	15.00 Ton		

FEED REQUIRED FOR GAINS

Corn:

Corn and alfalfa at the present time constitute the basal lamb fattening ration in Colorado. Figures on the value of other feeds used in the test are secured in a comparison with this ration.

Beet Molasses:

One hundred pounds of beet molasses replaced 104.7 pounds of corn and 26.2 pounds of alfalfa. Fed in limited quantities with corn and alfalfa the beet molasses proved more than equal to corn pound for pound in putting on gains.

Barley:

Where barley was fed with molasses and alfalfa, the lambs required approximately 10.7 per cent more grain, 10.6 per cent more molasses, and 11.2 per cent more alfalfa to make the same gain as those on the corn, molasses and alfalfa combination.

Oats:

The lambs fed oats required 7.7 per cent more grain, 7.6 per cent more molasses, and 11.3 per cent more hay per 100 pounds gain than lambs in the similarly fed corn lot.

Dried-Molasses-Beet-Pulp:

The combinations fed in the three lots receiving dried-molasses-beet-pulp were planned to throw some light on the value of this feed, when fed as a "lone" carbohydrate and also when mixed in different proportions with corn.

When the dried-molasses-beet-pulp was fed alone with alfalfa, the lambs required 6 per cent more dried pulp and 4.3 per cent more alfalfa to put on the same gains secured by corn and alfalfa. Where one-third of the grain mixture was dried pulp, 100 pounds of the pulp saved 104.4 pounds of corn, but the lambs ate 41.3 pounds more alfalfa. When dried-molasses-beet-pulp was fed, mixed in equal proportion with corn, 100 pounds of the dried pulp replaced 109.7 pounds of corn and 25.4 pounds alfalfa.

Wet Beet Pulp:

One ton of wet pulp replaced 222.1 pounds of corn and 208.0 pounds of alfalfa in putting on gains.

BUSINESS STATEMENT

November 27, 1920 to March 9, 1921
Based on Actual Receipts of Lambs
(Data for One Average Lamb)
All weights in pounds

Ration Fed*........	Corn	Corn Molasses	Barley Molasses	Oats Molasses	Dried Molasses Beet Pulp	Corn (½) Dried Molasses Beet Pulp (½)	Dried Molasses Beet Pulp (1-3) Corn (2-3)	Corn, Wet Pulp
Lot Number.......	1	2	3	4	5	6	7	8
Av. Initial Weight, Fort Collins......	70.7	71.0	71.1	71.1	71.2	70.8	70.9	71.3
Av. Final Wt. Ft. C.	101.8	103.3	100.3	101.2	100.4	103.5	102.3	105.5
Av. Final Wt. at Kansas City......	92.8	93.8	90.3	90.9	89.7	92.8	92.8	95.0
Percent Shrink, Ft. C. to Kansas City	8.79	9.25	9.93	10.10	10.65	10.32	9.24	9.93
Total Gain.........	22.1	22.8	19.2	19.8	18.5	22.0	21.9	23.7
Cost at Feed Lot Per Cwt..........	11.28	11.28	11.28	11.28	11.28	11.28	11.28	11.28
Initial Cost at Feed Lot.............	7.98	8.01	8.02	8.02	8.03	7.99	7.99	8.04
Cost of Feed 93 Days**..........	2.97	2.86	2.97	3.02	2.53	2.76	2.95	2.43
Cost of Labor......	.26	.28	.28	.28	.26	.26	.26	.56
Int on Invest. 8%..	.22	.22	.22	.23	.22	.22	.22	.22
Int. on Equip. 6%..	.05	.05	.05	.05	.05	.05	.05	.06
Shipping & Selling Expense #.......	.76	.77	.74	.74	.73	.76	.76	.78
Total Cost at K. C..	12.24	12.19	12.28	12.34	11.82	12.04	12.23	12.09
Selling Price per Cwt	8.75	8.65	8.00	8.50	8.25	9.00	9.00	8.65
Selling Price per Lamb...........	8.12	8.11	7.22	7.73	7.40	8.35	8.35	8.22
Net Return per Lamb...........	—4.12	—4.08	—5.06	—4.61	—4.42	—3.69	—3.88	—3.87
Necessary Selling Price per Cwt. K. C. to break even..	13.19	13.00	13.60	13.58	13.18	12.97	13.18	12.73
Dressing Percent....	50.6	50.4	49.7	49.0	49.0	51.3	50.5	51.8

*All Lots Self-fed Alfalfa Hay.

**Shelled Corn..	$1.35 per Cwt.	Dried Molasses Beet Pulp.	$18.40 per Ton
Barley.........	1.50 per Cwt.	Wet Pulp....................	1.25 per Ton
Oats.........	1.50 per Cwt.	Alfalfa........................	14.40 per Ton
Molasses......	15.00 per Ton		

#Freight was paid to river on original car of lambs.

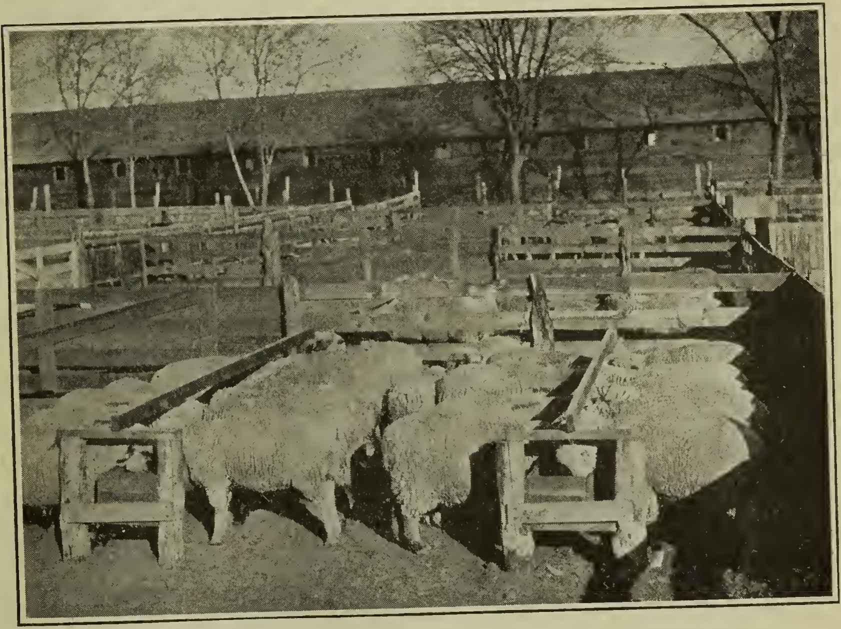
SHIPPING SHRINK

The lambs were unloaded twice en route to Kansas City. They were fed hay at North Platte and were held three days on hay and grain at Bismark Grove. On account of poor conditions met with at Bismark Grove and because the lambs had to be separated into the different lots before being sold, the shrink is probably greater than would appear under ordinary conditions. All lots were treated exactly alike, however, in order to obtain a true comparative shrink.

LABOR ESTIMATE

The cost of labor, where different rations are fed, is an important consideration. Labor costs, of course, must depend largely on distances feed must be hauled. Under ordinary conditions, where the hay fed is raised on the place and the grain haul is reasonably short, one man and team can haul and feed hay and grain to 1,750 lambs. Under similar conditions two men with one team can feed about 4,000 lambs.

When molasses is added to a grain-alfalfa ration and a three-ton tank is used, an additional man and team will be necessary every sixth day during the feeding period to haul



Doing Their Best to Make Cheap Gains. A Representative Lot on Feed at the Experiment Station.

molasses. With this force 4,000 lambs can be fed a quarter of a pound of molasses in addition to grain and hay.

When wet pulp is fed along with corn and alfalfa, one man and team ought to haul and feed grain and hay to 3,500 lambs, while two men with teams should haul twelve tons of pulp daily up to about four miles. This estimate considers that the lambs would only need about a half ration of corn and alfalfa when fed nearly seven pounds per head of the wet pulp. These figures are taken from data secured from observation and inquiry and represent an average which can be influenced by distance and ability of the men concerned.

There should be no extra labor cost over that of the check lot in feeding the dried-molasses-beet-pulp in addition to the corn.

SELLING PRICE PER CWT.

The lambs fed corn and dried pulp mixtures brought the highest price per pound on the market. The lambs in the check lot fed corn and alfalfa sold for 25 cents per cwt. less, because of several lambs that had not finished as well as those on the mixtures.

In the lots fed barley and oats the lambs did not show the finish secured in the corn fed lots. The lambs fed wet pulp were cut in price due to their heavier appearance and would doubtless have commanded a top price had they been nearer the handyweight size. In this case their loss would have been only $3.54 per head.

DRESSING PERCENT

The wet pulp lambs were the heaviest dressers, being followed by the half and half corn and dried pulpers. An examination of the lambs after they were slaughtered seemed to indicate that the wet pulp as well as the corn and dried pulp lambs were just as firmly fleshed as were those fed the straight corn ration.

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